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The evolution of animal husbandry in Neolithic central-west Anatolia: the zooarchaeological record from Ulucak Höyük (c. 7040–5660 cal. BC, Izmir, Turkey)

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Abstract

Research into the emergence of animal husbandry west of the Taurus mountains has been primarily confined to central Anatolia, the Lake District and the Marmara region in Anatolia, leaving a c. 85,000km^2 area in western Anatolia largely unexplored. This vast region is crucial to understand the developmental trajectories of early farming practices in Anatolia and to explain the expansion of Neolithic agro-pastoralist lifeways into southeast Europe. The hand-collected faunal assemblage from Ulucak Höyük near Izmir provides a first opportunity to examine the beginnings and the evolution of Neolithic animal husbandry practices in this region across an uninterrupted cultural sequence dating between c. 7040–5660 cal. BC. Taxonomic, osteometric and demographic analyses suggest that all four initial food animals (sheep, goat, cattle and pig) appeared simultaneously at the beginning of the seventh millennium BC. The relative proportions of the domestic food animals indicate that beef was as significant a resource as sheep and goat meat. Fusion data for cattle and combined tooth-eruption and wear data for sheep and goat suggest that milk exploitation may have begun towards the end of the seventh millennium BC and intensified during the first quarter of the sixth. Evidence for post-adult caprines and cattle is thought to represent a strategy employed to maximise herd size and buffer risk. No clear evidence for cattle traction was found. Fallow deer seems to have become an increasingly important resource throughout the period. Small amounts of fish remains and substantial amounts of marine molluscs demonstrate that coastal environments were also exploited. These results indicate that central-west Anatolia played an essential role in the expansion of animal husbandry technologies into southeast Europe.

Özet

Anadolu'da, Toros dağlarının batısında, hayvancılığın ortaya çıkışı ile ilgili araştırmaların daha çok orta Anadolu, Göller Yöresi ve Marmara bölgesi ile sınırlı kalmış olması nedeniyle Batı Anadolu'da yaklaşık 85.000 km^2'lik bir alan büyük ölçüde keşfedilmemiş durumdadır. Bu geniş bölge, Anadolu'da erken tarım uygulamalarının gelişim evrelerini anlamak ve Neolitik dönem agro-pastoral yaşam yollarının güneydoğu Avrupa'ya yayılma biçimini açıklamak için çok önemli bir bölgedir. İzmir yakınlarındaki Ulucak Höyük'ten elle toplanan fauna örnekleri, bu bölgede yaklaşık olarak M.Ö. 7040–5660 arasına tarihlenen kesintisiz bir kültür dizisini ortaya koymuştur. Bu dizi Neolitik dönemde hayvancılığın başlangıcı ve gelişiminin incelenmesi için bize fırsat sunmaktadır. Taksonomi, osteometri ve demografi analizleri başlıca dört besi hayvanının (koyun, keçi, sığır ve domuz) M.Ö. yedinci binyıl başlarında birdenbire ortaya çıktığını göstermektedir. Yerel besi hayvanlarının karşılaştırmalı oranları, sığır etinin en az koyun ve keçi eti kadar önemli bir kaynak olduğunu göstermektedir. Büyükbaş hayvan verileri ile koyun ve keçi diş çıkarma ve aşınma verilerinin biraraya getirilmesi, süt kullanımının M.Ö. yedinci binyıl sonlarına doğru başlamış ve altıncı binyılın ilk çeyreğinde yoğunlaşmış olabileceğini göstermektedir. Yaşlı küçükbaş ve büyükbaş hayvanlara ait kanıtların sürü büyüklüğünü artırmak ve riski azaltmak için kullanılan bir stratejiyi temsil ettiği düşünülmektedir. Sığırın tarla sürmede kullanıldığına dair net bir kanıt bulunamamıştır. Alageyik, dönem boyunca giderek daha önemli bir kaynak haline gelmiştir. Az miktarda balık ve önemli miktarda deniz yumuşakçası kalıntıları, deniz kıyılarının da kullanılmış olduğunu göstermektedir. Bu sonuçlar, Batı Anadolu'nun orta kısımlarının, hayvancılık teknolojilerinin güneydoğu Avrupa'ya yayılmasında önemli bir rol oynadığını göstermektedir.

Although animal husbandry is seen as one of the fundamental aspects of the Neolithic expansion from southwest Asia into southeast Europe, relatively little is known about the ways in which animal husbandry was adopted and transformed in the intervening regions before it reached Europe. A few exceptions apart (for example Düring 2011a), recent references to c. 1,000 years of Neolithic animal husbandry west of the Taurus mountains and east of the Greek mainland are confined to a few islands of knowledge, such as the late adoption of domestic cattle at Çatalhöyük (Russell et al. 2005) and the apparent intensification of dairy processing in northwest Anatolia (Evershed et al. 2008; Thissen et al. 2010; Brami, Heyd 2011; Özdoğan 2011). Although this paradigm results from a persisting paucity of Neolithic research in Anatolia for the most part, for the rest, it results from a reluctance to address diversity and homogeneity in subsistence systems as cultural elements.

The present paper seeks to redress this deficiency by presenting an interpreted account of the evolution of animal husbandry in central-west Anatolia, based on a qualitative analysis of the animal remains from Ulucak Höyük located near Izmir. The zooarchaeological assemblage from Ulucak (c. 7040–5660 cal. BC) presents an unmatched opportunity to document change and continuity in cultural approaches towards herding in west Anatolia from the beginnings of the Neolithic period to the onset of the Chalcolithic 'dark ages' (Düring 2011b). In this first attempt to discuss a sizable zooarchaeological assemblage from this region and era, the present paper puts emphasis on (1) establishing the domestication status of the frequently represented mammalian taxa at Ulucak, pigs and cattle in particular; and (2) exploring the diachronic development of animal husbandry technologies at the site, with specific attention given to the development of the use of secondary resources (milk, fleece and traction). While the main aim of the paper is to provide a firm ground to inaugurate an opinion about a possible trajectory for early animal husbandry systems in west Anatolia, the paper also offers some preliminary suggestions to locate the evidence from Ulucak within the context of the westward expansion of Neolithic lifeways.

Ulucak Höyük: settlement history and environment

Ulucak Höyük is located on the Kemalpaşa plain c. 9km east of the Izmir bay, c. 221m above sea level (fig. 1). The mound is situated within easy reach of the Aegean littoral via the Belkahve pass, a natural passage that still serves as one of the main arteries between coastal and inland western Anatolia (fig. 2). The Kemalpaşa plain is watered by the Nif river, which runs a few hundred metres to the west and south of the mound. Geomorphological research indicates that the Nif did not change its course dramatically during the prehistoric occupation of the mound (Kayan 1999; Çilingiroğlu et al. 2004: 8). The mound rises c. 6m above the surface of the plain and covers an area of 120m by 140m (Çilingiroğlu, Abay 2005: 6).

Palynological research suggests high humidity levels and forested landscapes in western Anatolia during the Early Holocene (van Zeist, Bottema 1991: fig. 4; Eastwood et al. 1999; Vermoere et al. 1999). An interruption to these favourable conditions may have come by a global cooling event, the so-called 8,200 BP event (Pross et al. 2009), which is considered by some researchers as the triggering force behind the collapse of PPNB systems, the spread of farming into southeast Europe (Weninger et al. 2006) and the presumed social unrest in the late seventh millennium BC Lake District (Clare et al. 2008). Most other scholars (for example van der Plicht et al. 2011) see this climatic event as one of several elements that caused accelerated cultural dynamism at the end of the seventh millennium BC. At present, palaeoenvironmental proxies from western Anatolia are not sufficiently detailed to address the relationship between the 8,200 BP global climatic event and the cultural development of Neolithic Ulucak. Palaeoclimatic proxies for the Kemalpaşa plain are limited to a few remains of acorn (*Quercus* sp.) from the on-site deposits at Ulucak, indicating the presence of oak trees around the Neolithic settlement (Megaloudi 2005).

Although, likewise, little is known about the plant-based subsistence at Neolithic Ulucak, on-going macrobotanical studies confirm the presence of a 'full package of cultivars', such as einkorn wheat (*Triticum monococcum*), six-rowed barley (*Hordeum vulgare*), lentil (*Lens culinaris*) and green pea (*Pisum* sativum), from the earliest occupational phases onwards (Megaloudi 2005; A. Erkal, personal communication).

The Neolithic occupation at Ulucak continued seemingly without interruption between c. 7040–5660 cal. BC (table 1), roughly covering the time period between the end of the pre-pottery phases at Çatalhöyük's East Mound and the early phases of occupation at Çatalhöyük West in central Anatolia (Çilingiroğlu 2009; Çilingiroğlu, Çevik forthcoming). Excavations at Ulucak have revealed three major Neolithic occupational levels (VI–IV); the radiocarbon dates place the oldest level, VI, in the first half of the seventh millennium BC, the following occupational level, Level V, to c. 6600–6050 BC and the youngest, Level IV, between c. 6040–5660 cal. BC (table 1). Work into the earliest Neolithic level (Level VI, preliminarily defined with layers a and b) uncovered a red-painted, lime-plaster floor, badly-preserved architectural remains with painted plaster walls

Fig. 1. Sites mentioned in the text

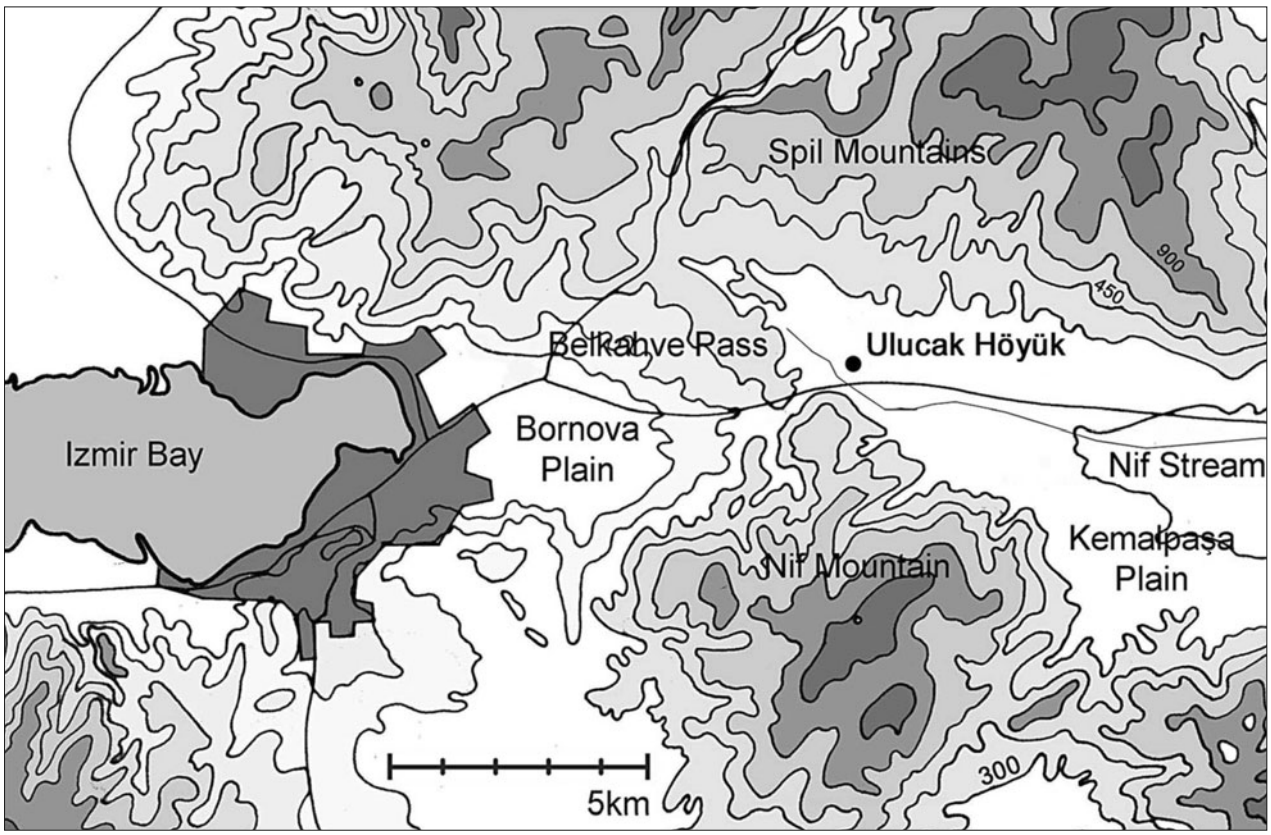


Fig. 2. Ulucak and its environs (courtesy of the Ulucak Project)

Occupational level	*Architectural phase*	*Cal. BC at 2 sigma range*	*Material analysed*
Level IV	IVa–k	6030–5660	Charcoal (n = 2), charred fruit (n = 1)
Level V Late	Va–c	6590–5885	Marine shell (n = 1), charred seeds (n = 2), charcoal (n = 8)
Level V Early	Vd–f	6660–6030	Charcoal (n = 10)
Level VI	VIa–b	7040–6470	Charcoal (n = 5), bone collagen (n = 2)

Table 1. Stratigraphic sequence and summary of calibrated AMS radiocarbon date ranges from Neolithic Ulucak (based on Çilingiroğlu 2009; Çilingiroğlu, Çevik forthcoming)

and several fire-related installations surrounded by ashy deposits in a single 10m by 10m area (Area L13). Level VI deposits are devoid of ceramic finds or any other clay objects, and are tentatively regarded as 'aceramic' (Çilingiroğlu, Çevik forthcoming). Virgin soil below Level VI was reached through coring in 2011. The subsequent level (Level Va–f) is distinguished from Level VI by its pottery and contains architectural remains that consist of rectangular wattle-and-daub houses. One exceptional case in the architectural tradition of Ulucak V is a building with massive stone foundations in Level Vd (Çilingiroğlu 2009: 43). The youngest Neolithic level (Level IV, layers a–k) is characterised by mud-brick architecture set on stone foundations, which were laid out around an open area. This level is contemporary with the Early Chalcolithic period in Anatolia, a time period which was originally defined by the appearance of a painted pottery tradition in the early sixth millennium BC settlements of the Lake District (Mellaart 1964). This radical change in pottery traditions does not occur in central-west Anatolia, a region which otherwise maintained strong affiliations with the Lake District cultures (Çilingiroğlu 2009: 29). Although whether or not Ulucak's Level IV should be labelled as 'Early Chalcolithic' is open to debate, for the time being, Level IV at Ulucak is considered as part of the Neolithic period (Çilingiroğlu 2009: 29). Late Chalcolithic (Level III), Early Bronze Age II (Level II) and late Roman to early Byzantine (Level I) remains overlay the Neolithic occupation on the mound (Çilingiroğlu et al. 2004).

In order to detect diachronic patterns in the faunal record while allowing for sufficient sample sizes, the zooarchaeological results are discussed in four broad chronological clusters representing Level IV, Level V Late (Va–c), Level V Early (Vd–f) and Level VI. The division made here between the earlier and later phases of Level V is somewhat arbitrary, taking the large stone building of unknown layout and function in Level Vd as a stratigraphic dividing line. Continuity in material culture is uninterrupted throughout Level V.

The occupational sequence at Bademağacı Höyük in the Lake District of Anatolia provides the closest chronological correlation with Ulucak and contains similar material culture features (Çilingiroğlu 2009a: 288–99). However, no aceramic layers have been attested at Bademağacı Höyük (Duru 2008: 17–19). While the material culture of Neolithic Ulucak displays strong affinities with the Neolithic cultures in central Anatolia, the Lake District, northwest Anatolia and southeast Europe (Çilingiroğlu et al. 2004; Çilingiroğlu, Çilingiroğlu 2007; Çilingiroğlu 2009; 2010), evidence from Ulucak and other Neolithic excavations in the region (Derin 2007; Lichter, Meriç 2007; Sağlamtimur 2007) demonstrates a distinct cultural zone in central-west Anatolia (Çilingiroğlu 2009; Sagona, Zimansky 2010: 82; Brami, Heyd 2011).

Material and methods

Data from 21,852 hand-collected vertebrate remains weighing almost 112kg are presented below. Excavations, as well as zooarchaeological analyses, continue. Due to difficulties regarding data compatibility, the 307 vertebrate specimens from Ulucak Levels IV, Va and Vb published by Trantalidou (2005) have not been merged with the material presented here. The analysis of the archaeofaunal material from the sieved deposits is currently underway. Here, interpretations rely on the remains of large and medium-sized mammals such as cattle, sheep, goat and pig, which are least likely to have been affected by sampling through hand-collection (Payne 1972).

While the zooarchaeological material dating between 6100–5660 cal. BC (Level IV) has been yielded through operations in various squares (L12–13, M13, N11–13, O11–13 and P11 on the grid system) distributed across the site, older material comes only from Square L13, where layers underlying Level IV have been investigated. This chronological inconsistency in the provenance of the Neolithic assemblage from Ulucak may cause discrepancies in the zooarchaeological record, but their effects are difficult to specify until excavations proceed down to lower layers in other trenches.

Identification, recording and quantification

Most of the expected taxa were fairly easy to distinguish based on their osteological morphology when diagnostic portions were present. However, the notorious difficulties in distinguishing between sheep and goat (Boessneck et al. 1964; Prummel, Frisch 1986) were encountered in the analysis of the Ulucak assemblage. Despite recent advances in developing useful morphological criteria to tell the two species apart (Halstead et al. 2002; Zeder, Pilaar 2010; Zeder, Lapham 2010; Gillis et al. 2011), problems with building reliable sheep/goat ratios based on sufficient sample sizes persist and are valid for this study. To clarify by what is meant by a sheep specimen and what is meant by a goat specimen, it is probably best to spell out which specific criteria were used to distinguish them. In the present study, the postcranial bones of sheep and goats were differentiated according to Zeder and Lapham's (2010) criteria. To identify the cranial bones, Boessneck et al.'s (1964) criteria were used. Most of the proposed criteria are applicable to skeletally mature elements, hindering reliable reconstructions of species-specific demographic profiles for archaeological sheep and goat populations. Because the criteria are most visible on measurable bones, although the size indices of sheep and goat populations could be considered separately for each species, the epiphyseal fusion data could not be grouped into sheep and goat. The identification of sheep and goat mandible teeth followed Zeder and Pilaar 2010. But, as a recent assessment indicates (Gillis et al. 2011), the distinguishing features of caprine teeth are still not entirely clear; this was empirically experienced during the analysis of the material from Ulucak. As a consequence, a large amount of the caprine mandibles in the sample from Neolithic Ulucak remains identified only as 'sheep or goat (*OVIS/CAPRA*)'.

Various methods of quantification have been devised in zooarchaeology to reveal past patterns of animal use, all with claims to overcome taphonomic biases and, despite that, all with a variety of drawbacks (Uerpmann 1973; Davis 1987; Reitz, Wing 2008: 183–250). In this study, vertebrate remains were counted and weighed to the nearest 0.1g for the basis of all quantified analyses. Isolated fragments, complete elements, articulated skeletons or skeletal parts, jaws with teeth, and fresh and old broken fragments that joined together were considered as single specimens, which constitute the basis of NISP (= Number of Identified Specimens) counts. The WIS (= Weight of Identified Specimens) is considered to be a rough proxy to estimate the relative contribution of closely-related vertebrate species to the diet in terms of meat yields, since bone weight coarsely correlates with body mass (Uerpmann 1973; Boessneck 1992; Zeder 1998). While the NISP is affected by a number of factors, including the differential number of skeletal elements and fragmentation (Lyman 2008: 29–30), calculations of the WIS are likely to have been affected by differential biochemical processes (for example heat) that cause loss of bone substance (Uerpmann 1973; O'Connor 2000; Lyman 2008: 102–08). These two quantification methods were used because the NISP is the only common unit of quantitative analysis available for relevant Neolithic sites in Anatolia and thereby most suited to monitor diachronic patterns in a regional context, whereas the WIS counts aid a closer estimation of the relative dietary contribution of major mammalian taxa at Ulucak itself where fragmentation rates are known to vary across different analytical units (see table 2 and discussion below).

In order to avoid taxonomic confusion for the non-specialised reader and to overcome the difficulties of multiple binominal nomenclatures used by zoologists for domestic taxa, uninominal names are used to denominate domesticates (for example *BOS*) throughout the text, following Uerpmann (1993).

Taphonomy

The taphonomy of archaeological bone and shell assemblages has important effects on palaeoeconomic interpretations (Lyman 1994). In order to identify the possible negative effects of specific taphonomic processes on taxonomic abundances and other analytical results, different sources of taphonomic evidence were quantified for each chronological unit (table 2). Percentages of complete skeletal elements and limb bones with epiphyses and/or metaphyses (i.e. the portions with most diagnostic traits), as well as mean specimen weights, were considered as indices for fragmentation and taphonomic loss. Index values fluctuate across different chronological units, with no clear chronological covariation, suggesting that several factors were responsible for fragmentation, some of which are incalculable.

As indicated by the low percentages of complete skeletal elements, the assemblage is extremely fragmented. The proportions of skeletal portions with diagnostic traits are likewise generally low. Fragments representing medium-sized mammals, which constitute the largest taxonomic group in the assemblages at all phases, are very small. All these factors hampered identification during the analysis. This is evident in the clear negative correlation between the chronological changes in the mean weight of these fragments and the changes in the proportion of unidentified vertebrate remains through different chronological units. With the exception of several samples from the burnt layers of Level IV (IVb in particular), few specimens were charred or calcined. The

	Level	VI	V Early	V Late	IV
Indices of fragmentation					
% of complete skeletal elements		1.90%	2.60%	2.80%	3.10%
% of limb bones with epiphyses and/or metaphyses		32.00%	29.80%	29.70%	31.70%
Mean weight (in g) of fragments representing medium-sized mammals (unidentified medium-sized mammals and identified medium-sized ungulates)		2.30	4.20	5.70	3.80
Mean weight (in g) of fragments representing large-sized mammals (unidentified large-sized mammals and identified large-sized ungulates)		18.70	18.80	19.70	21.50
Burning					
% of burnt (charred and calcined only) fragments		0.50%	0.80%	2.90%	13.80%
Food processing and tool manufacturing					
% of specimens modified during marrow and grease extraction		0.80%	0.50%	0.10%	0.20%
% of specimens with cut and chop marks		0.80%	1.10%	1.20%	0.50%
% of specimens with traces of working (work waste, ad-hoc tools, used splinters, etc.)		3.30%	3.80%	0.10%	3.30%
Modification by commensal animals					
% of specimens with traces of carnivore activity (chewing, licking, puncturing, etc.)		0.10%	0.80%	1.10%	3.50%
% of specimens with traces of rodent activity (gnawing)		1.10%	1.80%	1.60%	1.20%
% of specimens with modification by unidentified animals (e.g. digestion)		0.01%	0.00%	0.00%	0.07%

Table 2. Chronological taphonomic summary of the vertebrate remains

situation in Level IV had a negative impact on the identifications, because most of the burnt specimens had lost their morphological traits. Common sources of intentional bone fragmentation include food processing, especially marrow and grease extraction, and tool manufacturing, especially in Levels VI, V Early and IV (table 2). The destructive effects of these activities on the bones of medium-sized mammals is visible as the covariation between the chronological changes in the mean size of specimens representing medium-sized mammals and the frequency of specimens bearing traces of human-induced modifications. Bone alteration by commensal animals was not so common, although in Level IV carnivore activity may have been a relatively more important cause of fragmentation. No clear covariation was found between the chronological patterns of the observed taphonomic traits and the chronological trends in the taxonomic, morphometric and mortality data acquired from the assemblage, indicating that these secondary data were not negatively affected by taphonomic conditions in any way that would have a predictable impact on the palaeoeconomic interpretations presented in this paper.

Domestication status

Theoretically, domestication processes may take place in all areas where appropriate progenitors are distributed. In the cases of cattle, pigs and goats, the distribution areas of the ancestral forms include western Anatolia (Uerpmann 1987). Although zooarchaeological and genetic research clearly demonstrate that availability did not necessarily lead to independent domestication events (Uerpmann 1979; von den Driesch 1987; Zeder, Hesse 2000; Edwards et al. 2007), the possibility of local domestication events for aurochs and wild boars in Europe and its eastern peripheries is still subject to investigation (Götherström et al. 2005; Larson et al. 2007; Bollongino et al. 2008). Changes in taxonomic composition, demographics and morphology are taken as the main signatures of domestication status (Uerpmann 1979; Hemmer 1990; Zeder, Hesse 2000). Since the earliest occupational level of Neolithic Ulucak dates to c. 7000 BC, pre-dating the introduction of domestic pig and cattle both in central Anatolia (Russell, Martin 2005) and the Balkans (Brami, Heyd 2011), the domestic status of these animals, as well as sheep and goats, was questioned for Neolithic Ulucak.

The overall sizes of cattle, pig, sheep and goat populations were explored throughout the cultural sequence, using the Logarithmic Size Index (= LSI) method (Uerpmann 1979; Meadow 1981). The application of the LSI method follows Meadow (1999). The post-cranial measurements are those described by von den Driesch (1976). The standard animals are specimens which are commonly used in Anatolian zooarchaeology: a female Mesolithic aurochs (*Bos primigenius*) from Denmark (Degerbøl, Fredskild 1970); a modern female wild boar (*Sus scrofa*) from eastern Anatolia (Hongo, Meadow 2000); a female wild sheep (*Ovis orientalis*) from Turkey (Uerpmann, Uerpmann 1994); and the mean measurements of a female and male wild goat (*Capra aegagrus*) from the Taurus mountains (Uerpmann, Uerpmann 1994). Although it would be ideal to compare the size indices of ungulate mammals from Ulucak with corresponding data from local Late Pleistocene and Early Holocene populations, such data are currently unavailable. The distributions of logarithmic size indices are expressed in histograms drawn for each occupational level (figs 4, 6, 7 and 10), in which '0' on the horizontal axis represents the standard animal and the number of observations in each interval (0.1) is provided above each column.

Herd structure and mortality

Because methods of human exploitation manipulate herd structures – wild and domestic – zooarchaeological interpretations of procurement strategies largely derive from quantified reconstructions of herd demographics, i.e. mortality profiles and sex ratios. For the reconstruction of mortality profiles, fusion and ossification states of limb bones as well as tooth eruption and wear patterns were used. The fusion data are limited in their helpfulness to reconstruct mortality profiles, because they only provide information about whether an animal died before or after a particular bone had been fused, allowing generalised estimations of age at death. Aside from this, the more porous structures of unfused bones are more prone to taphonomic loss, potentially creating a bias in the mortality profiles generated through fusion data. Epiphyseal data can nevertheless be useful indicators of changes in mortality rates through time, gross differences in the exploitation of different taxa and in cases where sample sizes for dental data are not sufficient. Clustered column charts (figs 5, 9, 12 and 14) that show the number of fused specimens as percentages of the total number of observations (fused and unfused specimens) at each fusion stage provide a rough idea as to the proportions of individuals that survived each stage.

Tooth eruption and wear data are better suited to reconstructing mortality profiles, because teeth are more resilient to taphonomic processes than bones. In addition, tooth wear continues throughout a lifetime, providing longer and more precise ranges for age at death estimations. Observations of tooth eruption and wear patterns in modern mammals provide recording schemes that enable accurate estimations of age groups in archaeological populations and cross-comparisons among analytical groups (Payne 1973; Grant 1982; Zeder 2006). Only data from teeth in mandible bones were used to generate the mortality profiles based on dental observations. Due to the small sample sizes and difficulties encountered during analysis in distinguishing sheep and goat mandibles, the mortality profiles for sheep and goats were combined. While Payne's (1973) method of ageing mandibles was taken as a basis to produce mortality profiles for sheep and goats, his suggestion to exclude mandibles without the fourth premolars (deciduous or permanent) was not followed; instead, during analysis, mandibles with teeth from each level were laid out and checked in terms of size, wear pattern and taphonomy in order to ensure that no mandible was represented with both sides. The dental-age recording system for Neolithic Ulucak followed Grant (1982) for cattle and pigs.

Sex, based on non-metric observations on ruminant acetabulae, horn core morphology in sheep and goats, and canine teeth in pigs, was also determined when possible, but quantifications deriving from these observations can be biased taphonomically. For example, when hornless female sheep are present in an assemblage, which is the case for that from Neolithic Ulucak, this situation causes inflated counts of male sheep and horned male and female goats (Hole et al. 1969). While female and male bovine acetabulae are readily distinguishable (Boessneck et al. 1964; Grigson 1982; Prummel, Frisch 1986), males tend to be slaughtered early in life while the organic content of their bones is still high, decreasing the chances of male acetabulae surviving in archaeological soils, thereby causing potentially underestimated male counts. Another method of estimating sex densities in populations of mammals that display pronounced sexual dimorphism – in the case of Anatolia, all the four ungulates in question (Payne, Bull 1988; Grigson 1989; Zeder, Hesse 2000; Atıcı 2011) – is observing the intra-population variation in size of single dimensions in the skeleton (for example the distal breadth of metacarpals: Zeder, Hesse 2000; Arbuckle et al. 2009), of combined dimensions in single elements (for example two separate dimensions of distal humerii: Davis 1987: 44–45) or logarithmic size indices (Uerpmann 1979; Meadow 1981; Payne, Bull 1988). In this paper, estimations of sex ratios are primarily based on signatures of sexual dimorphism (for example bimodality) in the LSI distributions, ratios of acetabulae ascribed to male and female individuals for ruminants and the easily sexable canine teeth for pigs.

Pathologies

Traces of pathological conditions, fractures and other osteological conditions stemming from human-induced stress may provide indirect evidence for management practices (Reitz, Wing 2008: 168–72). Pathological indicators on bone specimens were recorded when present. Since evidence for pathological conditions was rare, only the most relevant are discussed, such as the deformations in cattle extremities. Such deformations are typically caused by the exploitation of cattle as draught animals (Bartosiewicz et al. 1997; De Cupere et al. 2000), but deformations with low severity may also form as a consequence of the friction caused by an animal travelling over rough terrain (De Cupere et al. 2000). Such evidence from the Neolithic period may have important implications for our understanding of the development of the use of cattle in traction (Isaakidou 2006; Greenfield 2010).

	Level VI		*Level V Early*		*Level V Late*		*Level IV*		*Total Neolithic*	
Taxonomic descriptions	*NISP*	*WIS (g)*	*NISP*	*WIS (g)*	*NISP*	*WIS (g)*	*NISP*	*WIS (g)*	*Total NISP*	*Total WIS (g)*
Unidentified mammals	5,557	7,909	2,117	6,233	1,444	4,515	3,227	8,633	12,345	27,289
BOS (cattle)	336	6,798	394	8,913	391	8,696	335	9,170	1,456	33,576
OVIS (sheep)	168	1,291	96	1,153	140	1,840	143	1,312	547	5,595
CAPRA (goat)	42	293	55	709	47	505	62	724	206	2,231
OVIS/CAPRA (sheep/goat)	1,531	4,930	1,215	4,978	1,248	6,093	1,142	4,766	5,136	20,767
SUS (pig)	161	865	289	3,015	527	6,019	338	3,599	1,315	13,497
CANIS (dog)	1	2	1	7	10	146	18	201	30	356
BOS/Bos primigenius (cattle/aurochs)	17	1,491	1	117	2	85	3	143	23	1,836
CAPRA or Capra aegagrus (goat/wild goat)	3	33	5	94	9	136	10	186	27	459
CANIS/Vulpes vulpes (dog/red fox)	1	1	2	6	5	21	13	28	21	56
Dama dama (fallow deer)	36	307	36*	419	56*	850	150*	2,177	278	3,753
Cervus elaphus (red deer)			2*	31	1	23	6*	140	9	193
Dama dama/Cervus elaphus (fallow/red deer)	4	29	9	71	7*	35	33*	284	53	419
Capreolus capreolus (roe deer)	14	70	9	65	14	154	10	67	47	356
Sus scrofa (wild boar) (c.)	5	113	7	176	6	130	19	288	37	707
Panthera pardus (leopard)			1	13					1	13
Vulpes vulpes (red fox)	5	5	3	19	3	18	15	43	26	84
Martes foina (beech marten)							2	2	2	2
Meles meles (European badger)	1	2			1	1	3	23	5	25
Lepus europaeus (European hare)	20	22	36	64	30	66	147	224	233	376
Rodentia indet. (unidentified rodents)	2	1					3	2	5	3
Testudinidae indet. (unidentified tortoises)	2	2			3	7	15	60	20	68
Reptilia indet. (unidentified reptile)	1	1							1	1
Aves indet. (unidentified birds)	2	1	10	32	7	13	6	3	25	48
Sparus aurata (gilt-headed sea bream)							1	0	1	0
Pisces indet. (unidentified fish)	3	0							3	0
Totals	7,912	24,164	4,288	26,112	3,951	29,363	5,701	32,071	21,852	111,709

*Table 3. Taxonomic compositions based on NISP (= Number of Identified Specimens) and WIS (= Weight of Identified Specimens) per occupational level in Neolithic Ulucak. *Level IV yielded one* C. elaphus*, 26* C. elaphus/D. dama *and 14* D. dama *antlers. Twenty of these bear traces of use and working. In Level V Late, two* C. elaphus/D. dama *antlers and one* D. dama *antler were found. In Level V Early, two* C. elaphus/D. dama *antlers and one* D. dama *antler were identified; two bear traces of working. These specimens are included in this table*

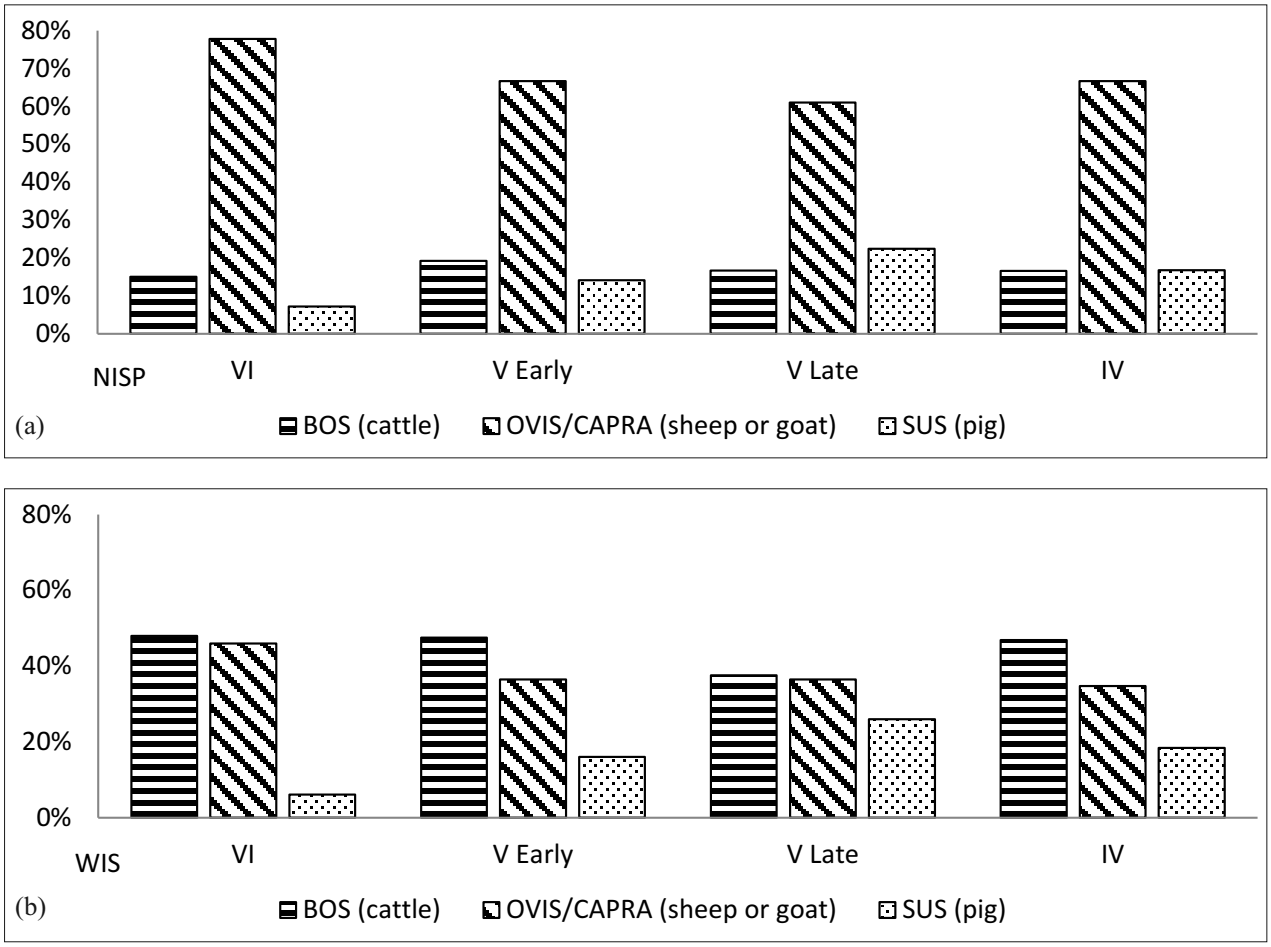


Fig. 3. Proportions of domestic food animals by occupational levels of Neolithic Ulucak based on NISP (a) and WIS (b) calculations

Results

It is clear that herding was one of the most important subsistence activities at Neolithic Ulucak. The remains of domestic animals dominate the vertebrate assemblages throughout the sequence (table 3), making up c. 91% of the total NISP and 90% of their weight. The importance of sheep (*OVIS*) and goat (*CAPRA*) herding from the beginnings of the occupation at Neolithic Ulucak is well attested by the high proportion of sheep and goat remains in Level VI, both in terms of the NISP calculations and the WIS (fig. 3). The average high proportion (44%) of cattle (*BOS*) among domestic food animals in terms of the WIS calculations indicates the large contribution of beef to the meat portion of the diet (fig. 3b). Similar to the case for cattle, the important average proportion (18%) of pig (*SUS*) remains in the total WIS of domestic food animals suggests that the contribution of this species in terms of meat gain is down-played by the NISP figures despite the larger number of skeletal elements individual animals have (fig. 3). The detailed zooarchaeology of each domestic food animal is discussed separately below.

Cattle

The relative abundance of cattle remains among the remains of food domesticates is no less than 15% in terms of the NISP at any occupational level (fig. 3a). The proportion of cattle in the NISP is slightly lower (by c. 2–4%) in Level VI than in subsequent levels. In contrast, based on the WIS calculations, the proportion of cattle remains relative to other domestic food animals is largest in Level VI, at 48% (fig. 3b). The high relative total weight of cattle remains is generally retained in the assemblages of subsequent levels; excluding a 9% decrease in the later phases of Level V. While this decrease seems to be largely conditioned by an increase in the weight of pig remains, it is probably sharpened by a simultaneous and marked increase in the mean weight of specimens representing medium-sized mammals, which positively influenced the identification of these specimens to lower taxa (table 2). The increase in the mean weight of medium-sized mammals is a consequence of a decrease in the intensity of processing medium-sized mammal bones for marrow and grease extraction as well as tool production (table

2 and 'taphonomy' section above). In view of this information, the decrease in the relative weight of cattle in Level V Late can be regarded as a reflection of a change in carcass processing and secondary use of bone material, and possibly an increase in pig remains, rather than as a significant decrease in beef production. In Level IV, the proportion of cattle among domestic food animals is high again, up to 47%, in terms of the WIS.

Logarithmic size indices demonstrate that a large majority of the cattle in Neolithic Ulucak were smaller than the standard female aurochs (*Bos primigenius*), strongly indicating that small domesticated cattle were present at the site from the beginning of the settlement (fig. 4). In Levels VI and V Early, few specimens are equally large as or slightly larger than the standard individual, suggesting that aurochs may also have been exploited at the beginnings of the settlement. Alternatively, such large measurements may represent large domesticated males or individuals that are at the incipient stages of the morphological changes accompanying domestication. Large cattle bones are present in later levels as well, but in even lower frequencies. The implications of large cattle specimens in older levels have to be investigated using a larger archaeofaunal sample from these levels. For the time being, the large cattle specimens in the assemblage have been tentatively ascribed as *BOS/Bos primigenius*; domestic cattle or aurochs (table 3). Horn cores with typical wild attributes are absent from the sample.

The palaeogenetic analysis of six morphologically domestic cattle bones from Levels V and IV disclosed that these cattle carried Type T3 and Q MtDNA lineages, which are typical of the domesticated taurine cattle and its ancestral form in the Fertile Crescent and Anatolia (Scheu 2011). As the palaeogenetic analysis of the cattle remains from Level VI is on-going, the vague tendency towards larger cattle in Level VI cannot be aligned with information from palaeogenetic research.

The overall size of the cattle population at Ulucak (fig. 4) is similar to the seventh millennium BC cattle from Bademağacı (De Cupere et al. 2008: fig. 9), Argissa-Magula in Thessaly (Boessneck 1962: 80–85) and Fikirtepe in Istanbul (Boessneck, von den Driesch 1979: table 5). While the size of Neolithic cattle from Ulucak falls within the range of smaller cattle from Neolithic Çatalhöyük, which have been shown to represent wild female aurochs (Russell, Martin 2005: fig. 2.8; Russell et al. 2005), in the absence of measurements that represent distinctly large individuals, the large majority of the cattle in Ulucak is considered to be morphologically domestic from the beginning of the occupation onwards.

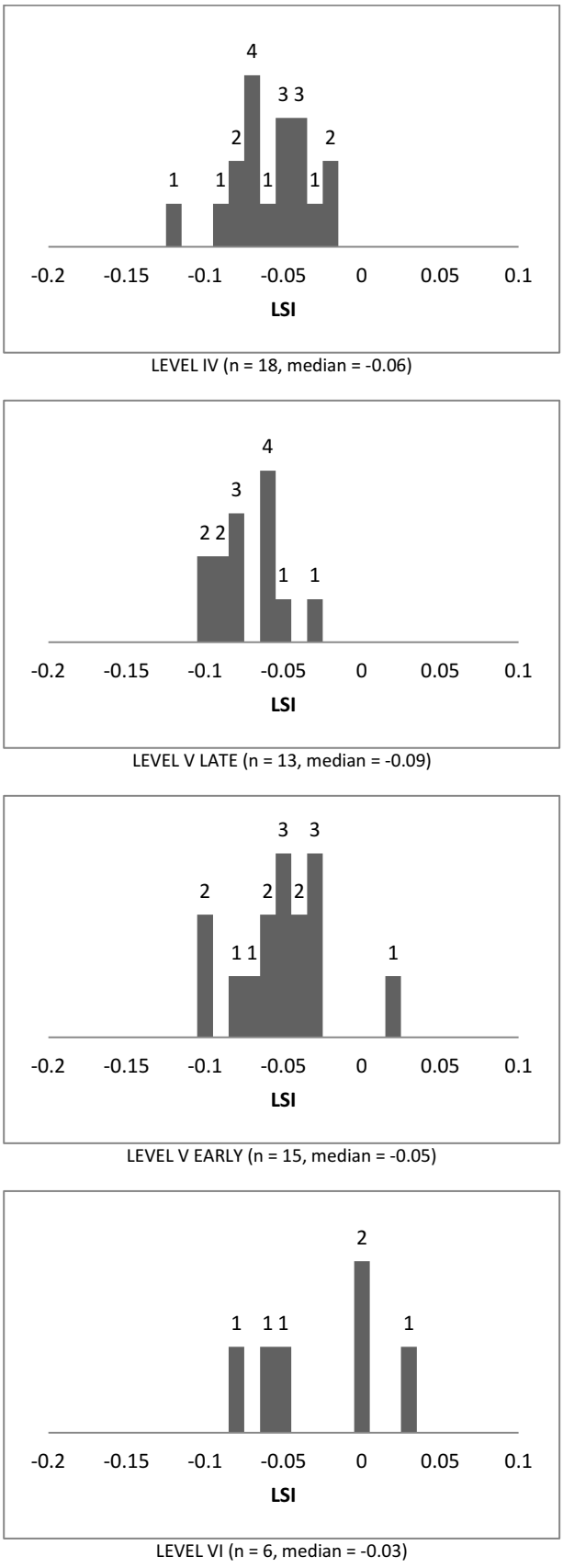


Fig. 4. Logarithmic Size Index (= LSI) data for cattle by Neolithic occupational level

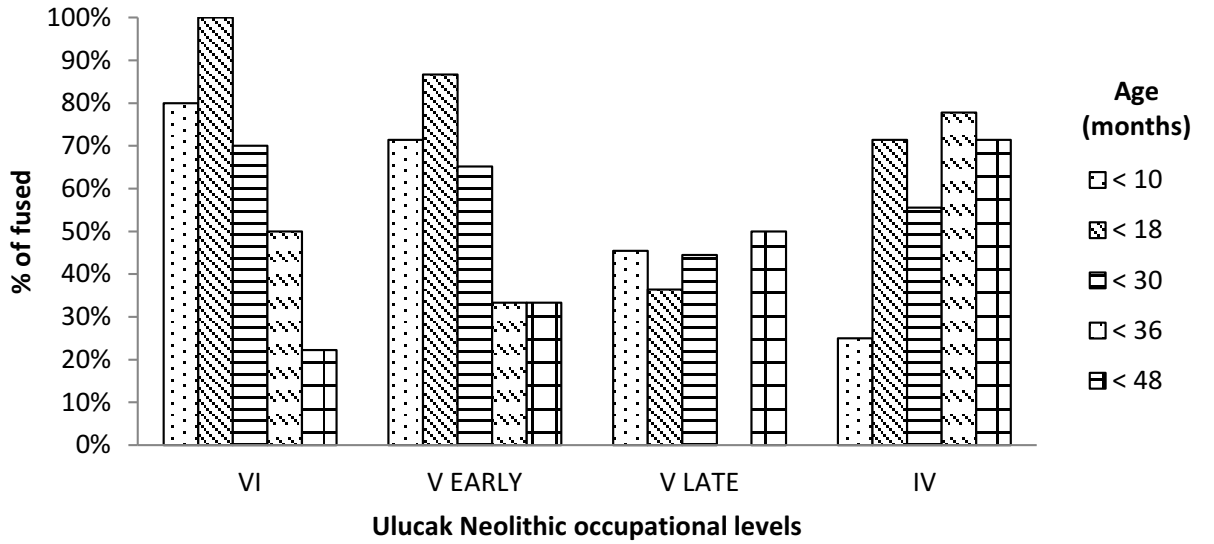
Due to the scarcity of cattle mandibles with teeth, loose permanent mandibular molars were also considered for estimations of cattle slaughter ages (table 4). A discrepancy is observed between mandible readings indicating an unusually high ratio (six out of seven) of individuals culled at old and very old age and the fusion data for cattle (fig. 5) demonstrating that culling before old age was frequent. This discrepancy can be explained by preservation factors that favoured old, thus more robust mandibles or small sample sizes. Even with the addition of loose teeth, sample sizes are still not adequate to allow diachronic observations based on dental data. In general, tooth wear and eruption patterns indicate that a small portion of the cattle (18%) was culled before reaching maximum size (at c. four years of age), while most individuals (60%) survived well beyond two and a half years (table 4).

The dental dataset was complemented by a sample of 212 long-bone specimens that provided fusion data, a likewise small sample size to monitor changes across more than 1,000 years of occupation (fig. 5). Nevertheless, based on this sample, certain diachronic trends can be inferred. The fusion data imply that slaughter age preferences for cattle may have gone through a gradual change towards an increasing interest in slaughtering individuals younger than seven to ten months. The interest in culling juvenile animals at the beginning of the Neolithic occupation likewise changed towards more frequent slaughter of pre-18-month-old animals in the subsequent levels. Specimens representing culling events up to 30 months seem to increase somewhat from c. 30% in Level VI to 54% in Level V Late, and then decrease down to 36% in Level IV. Culling events up to 36 months are markedly less frequent in the younger phases of the settlement than in the older. Specimens representing culling events before 36 months are frequent (50%) in Level VI; they are even more frequent (67%) in Level V Early. No data are available for this stage at Level V Late, creating a gap in the record. In Level IV, specimens representing culling events up to 36 months constitute a small minority (22%). Specimens indicating culling before 48 months are high in frequency (78%) in Level VI, gradually becoming less frequent towards the end of the settlement in Level IV (29%).

While the inconsistencies in these data are plenty and difficult to decipher, two chronological trends attract attention. Although these should be approached with caution, taking the small sample size and the possibility

	Level	*Side*	*Grant Stages (Grant 1982)*					*Estimated age*
			d4	*p4*	*m1*	*m2*	*m3*	
Mandibles with teeth	IV	L		k				Old
	IV	L			l	l	l	Very old
	IV	L			k	i		Old
	V Late	R			p	o		Very old
	V Early	R	g		1/2			Infant/juvenile
	V Early	R			k			Old
	V Early	L		d		j		Old
Loose mandibular permanent molars	V Late	R					d	Adult
	V Late	R					a	Young adult
	V Late	L					a	Young adult
	V Late	R					e	Adult
	V Late	L			m			Old
	V Early	R			g			Adult
	V Early	L			e			Young adult
	V Early	R				h		Old
	V Early	L					h	Old
	VI	R			g			Adult

Table 4. Cattle tooth wear and eruption data (following Grant 1982) by occupational level



	Age (months)	*Level VI*		*Level V Early*		*Level V Late*		*Late IV*	
	Perinatal specimens	0		5 (1%)		3 (1%)		1 (< 1%)	
Epiphyses		*Fused*	*Unfused*	*Fused*	*Unfused*	*Fused*	*Unfused*	*Fused*	*Unfused*
Distal scapula, pelvis	< 10	8	2	5	2	5	6	1	3
Proximal radius, distal humerus, proximal second phalanx	< 18	5	0	13	2	7	4	10	4
Proximal first phalanx, distal tibia, distal metapodia	< 30	7	3	15	8	8	10	10	8
Calcaneus tuber, proximal femur	< 36	1	1	1	2	0	3	7	2
Distal radius, proximal humerus, proximal tibia, ulna tuber	< 48	2	7	4	8	10	11	5	2
	Total no. of observations	36		60		64		52	

Fig. 5. Survivorship of cattle based on long-bone fusion ratios (following Habermehl 1975: 104–05)

of negative taphonomic effects into account, they may be relevant for the interpretation of culling practices in terms of the changing role of cattle in the subsistence economy of Neolithic Ulucak. The first of these trends is the increase in the frequency of culling events targeting individuals younger than ten months of age through time and the second is the chronological decrease in the specimens indicating culling events prior to three and a half years to four years of age.

No sex ratios could be estimated for the cattle populations of Neolithic Ulucak. Only a single *BOS* acetabulum from Level IV could be ascribed to a female individual. The sample of measured specimens is too small to deduce size densities as proxies for the sex ratios of adult populations.

A small number (n = 16) of cattle bones indicate signs of bone deformation as described and illustrated by Bartosiewicz et al. (1997). They all concentrate on metacarpals and phalanges, displayed as slight 'lippings' at their proximal articular surfaces. These deformations are barely visible; none of them being more severe than 'Stage 1' (i.e. earliest stage) deformations as defined by Bartosiewicz et al. (1997) based on their empirical observations of modern draught cattle in eastern Europe. No chronological trend is observed in their occurrence; they are present at all levels.

In summary, domestic cattle were an important resource at Neolithic Ulucak from the beginning of occupation. Up until the latter half of the seventh millennium BC, most cattle seem to have been slaughtered at adult size, perhaps optimising beef production in an effort to meet the demands of a growing population. Evidence of adults kept until old age may represent a risk-buffering strategy which demanded that individuals were not culled unless absolutely necessary. Culling events

before ten months of age and after three and a half to four years of age became gradually more frequent through the Neolithic occupation. This observation, especially marked in Level IV, implies a production goal additional to moderate beef production. This new goal may have been to maximise herd size by keeping stud cattle as a form of commodity. Such large stud individuals, however, do not appear in the logarithmic size indices of the younger levels. Large individuals that do show in the LSI record from the older layers are more likely, in fact, to represent management strategies geared towards keeping as many animals as possible. Although it could be argued that the use of cattle for traction may be responsible for this change in culling rates that favoured older individuals, the frequency and the level of weight-related deformations on cattle bones are too low to suggest the presence of draught cattle at Ulucak. A third management goal, namely milk production, is probably the most likely explanation for the increase in infant and old-age cullings in the younger phases of Neolithic Ulucak. Keeping large numbers of female animals, not only for reproduction purposes but also for milk production, is a key strategy in milk-producing subsistence economies (Payne 1973). Infant cullings may be necessary for milk production from primitive cattle (Balasse 2003; Vigne, Helmer 2007). A cattle management system that began to put gradually more emphasis on milk production towards the end of the seventh millennium BC, while optimising beef yields, is the most likely explanation for the chronological trends observed in the fusion data for cattle at Ulucak.

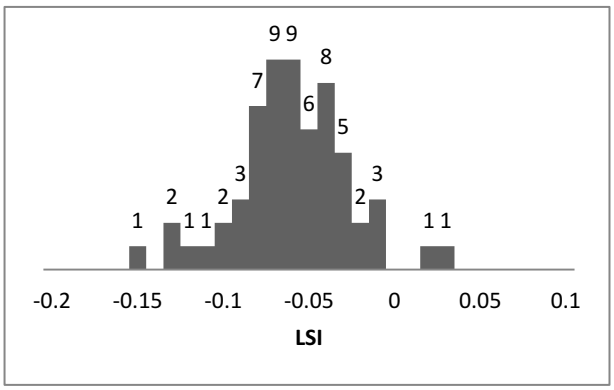
Sheep and goats

Sheep and goats comprised the largest group in the herds of Neolithic Ulucak (table 3, fig. 3). Based on specimen counts, the relative frequency of caprine remains is highest, at 78% of the remains of domestic food animals, in Level VI (fig. 3a). Their proportion decreases slowly and slightly throughout Level V, mainly due to the increase in the relative proportion of pigs. In Level IV, however, the proportion of sheep and goat increases as the proportion of pigs decreases. About 12% of the caprine specimens were identified as sheep and goat (table 3). The ratio of sheep to goats is c. 3:1, indicating that the composition of the caprine herds in Neolithic Ulucak was comparable to those proposed for contemporary sites in Anatolia, such as Bademağacı (De Cupere et al. 2008), Höyücek (De Cupere, Duru 2003) and Çatalhöyük (Russell, Martin 2005), where sheep herds were also dominant in the Neolithic landscape.

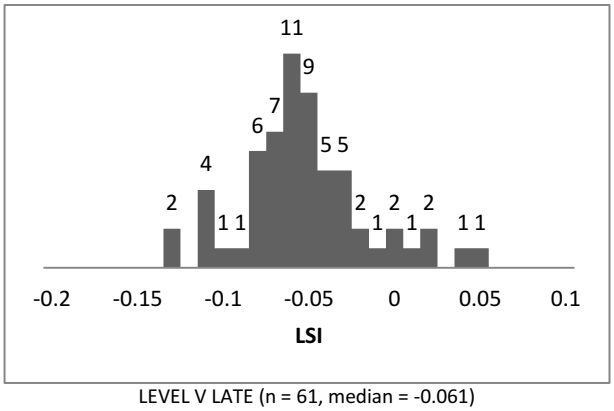
The presence of domestic sheep and goat at Neolithic Ulucak was to be expected. Sheep are considered to be outside their natural distribution area in west Anatolia (Uerpmann 1987) and caprines had been under human control in southwest Asia for almost 2,000 years prior to the beginnings of Neolithic occupation at Ulucak (Conolly et al. 2011). However, the proposed variety in the degree of human control on caprines among the Neolithic settlements in Anatolia during the late eight millennium BC raises questions as to whether morphologically domestic sheep and goats were, first of all, present in the earliest occupation of Ulucak and, secondly, whether their morphological state and evolution display parallels with the surrounding regions. For example, morphometric and demographic data show that while the population at Çatalhöyük was exploiting domestic caprines during the last quarter of the eight millennium BC (Russell, Martin 2005), for contemporary Suberde, located at the western part of south-central Anatolia, it has been proposed that sheep and goats were morphologically wild, but 'experimentally' managed (Arbuckle 2008a). When sheep and goat herds appeared in the Lake District and Greece during the second half of the seventh millennium BC, the populations were clearly marked by signatures of early domestication, such as diminished body size, modified and smaller horns, and the presence of hornless female sheep (von den Driesch 1987; De Cupere et al. 2008).

The logarithmic size indices of sheep remains at Ulucak exhibit a normal distribution, with the majority of values falling to the left of the standard wild female (fig. 6). Although some specimens are equally large or slightly larger than the standard, no specimen is clearly larger than the standard wild female, confirming the absence of *Ovis orientalis* (western Asiatic mouflon) in central-west Anatolia during the Early Holocene. The size range of sheep represented at Neolithic Ulucak is closely similar to that of the published data from contemporary central Anatolia (Russell, Martin 2005: fig. 2.21; Arbuckle 2006: fig. 5.39) and the Lake District (De Cupere et al. 2008: fig. 6). At the same time, the sheep of Ulucak appear to be smaller than those of the Pre-Pottery Neolithic sites in central Anatolia (for example Aşıklıhöyük: Buitenhuis 1997), further confirming the domestic status of the sheep populations exploited by the Neolithic inhabitants of Ulucak. These morphological differences and similarities are strong indications, meeting expectations, that sheep arrived in central-west Anatolia in domesticated form through the expansion of Neolithic life-styles.

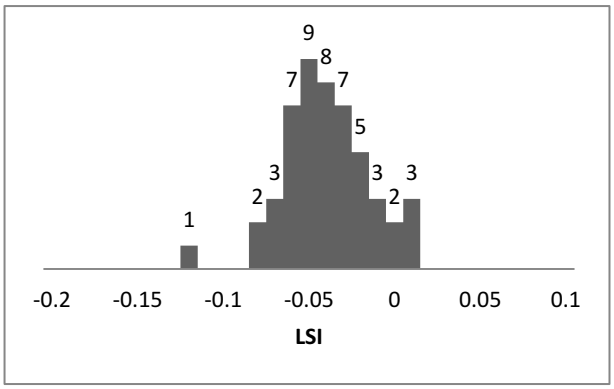
After their initial appearance in the earliest excavated layer of Ulucak, a slight decrease may have occurred in the size of sheep (fig. 6). Large specimens are present throughout the sequence, but the overall distribution of the indices moves towards lower values in younger levels. Changes in the demographic structure



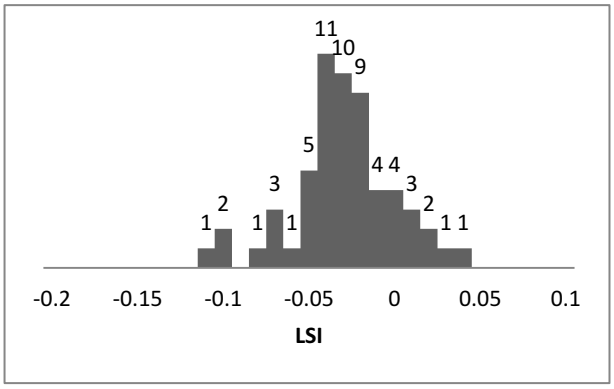
LEVEL IV (n = 61, median = -0.067)



LEVEL V LATE (n = 61, median = -0.061)



LEVEL V EARLY (n = 51, median = -0.046)



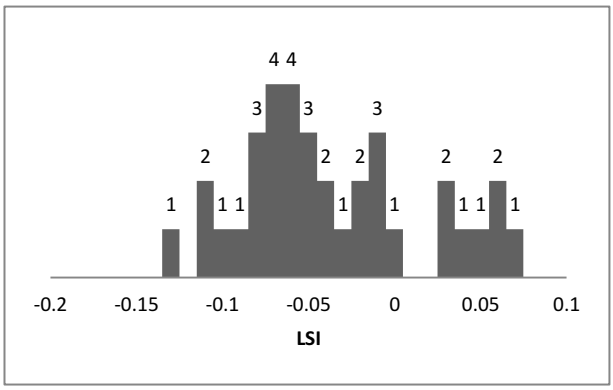
LEVEL VI (n = 58, median = -0.037)

Fig. 6. Logarithmic Size Index (= LSI) data for sheep by occupational level

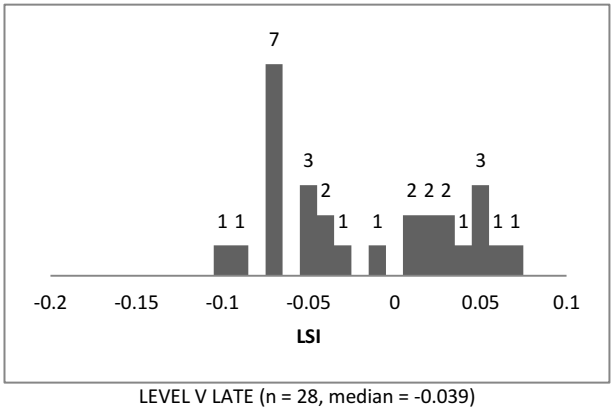
of caprine herds (figs 8 and 9; and discussion below) may be partially responsible for this apparent trend. Due to the sexual dimorphism displayed by caprines, managing domestic caprine herds by keeping a large number of females into old age and culling males young may reflect on size indices as an imitation of overall body size diminution (Zeder, Hesse 2000; Zeder 2001). At Ulucak, while the number of observations for caprine sex ratios is not sufficient to argue that the slight shift in size distributions is a reflection of prolonged lives for female caprines, kill-off patterns generated from combined dental eruption and ware data demonstrate that, in the younger levels, relatively more individuals, perhaps females, survived to full height and weight (fig. 8), causing a chronological shift in logarithmic size indices. Parallel changes in sheep size have been observed in the Neolithic Lake District and Thessaly (von den Driesch 1987; De Cupere et al. 2008). However, the apparent changes in sheep osteometrics are not large enough to infer a major shift in the overall body size in any of the regions in question, including central-west Anatolia.

In the case of goats, although the majority of logarithmic size indices are smaller than the standard (fig. 7), quite a few values are clearly larger than the modern standard and the mean values provided for eighth millennium BC sites to the east, such as Aşıklıhöyük (Buitenhuis 1997) and Suberde (Arbuckle 2008a: fig. 4), and comparable with the lower range of wild goats (*Capra aegagrus*) from the Epi-Palaeolithic cave of Direkli further east in Anatolia (Arbuckle, Erek 2010: fig. 5). The large goat specimens from Ulucak may represent either wild goats (*Capra aegagrus*) or large stud males (table 3). Although it is tempting to associate the increase in large-sized goat specimens in Level IV with the increase in the relative proportion of other wild mammals in the same level (table 3), in the absence of morphologically wild goat horns from Ulucak, specimens providing these measurements and a few other large goat specimens with no measurable dimensions have been designated as *CAPRA/Capra aegagrus*. The LSI distributions of goats are slightly skewed towards the lower end of the index, suggesting a larger proportion of adult females at all levels. Phased sample sizes for goats do not allow observations on chronological changes in size.

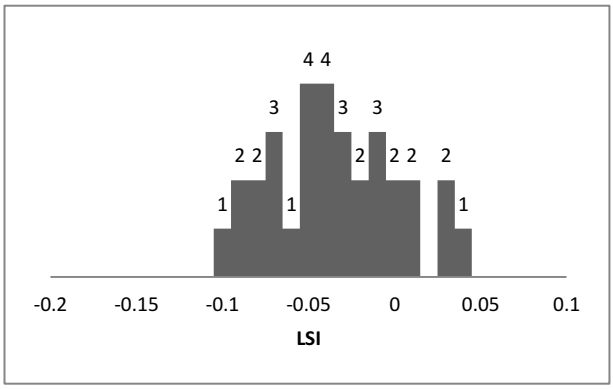
A sample of 110 mandibles was available for the reconstruction of sheep and goat mortality patterns based on tooth wear and eruption (table 5). Sample sizes for each chronological cluster are adequately balanced, enabling reasonable comparisons of the mortality profiles generated for each level (fig. 8). The mortality profiles generated for the earliest levels, VI and V Early, are remarkably similar, indicating that culling targeted



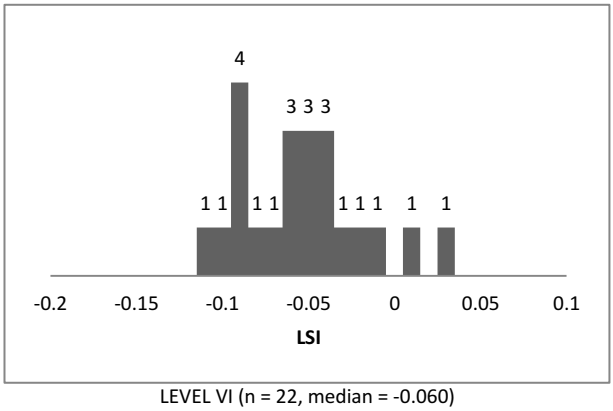
LEVEL IV (n = 35, median = -0.057)



LEVEL V LATE (n = 28, median = -0.039)



LEVEL V EARLY (n = 32, median = -0.045)



LEVEL VI (n = 22, median = -0.060)

Fig. 7. Logarithmic Size Index (= LSI) data for goat by occupational level

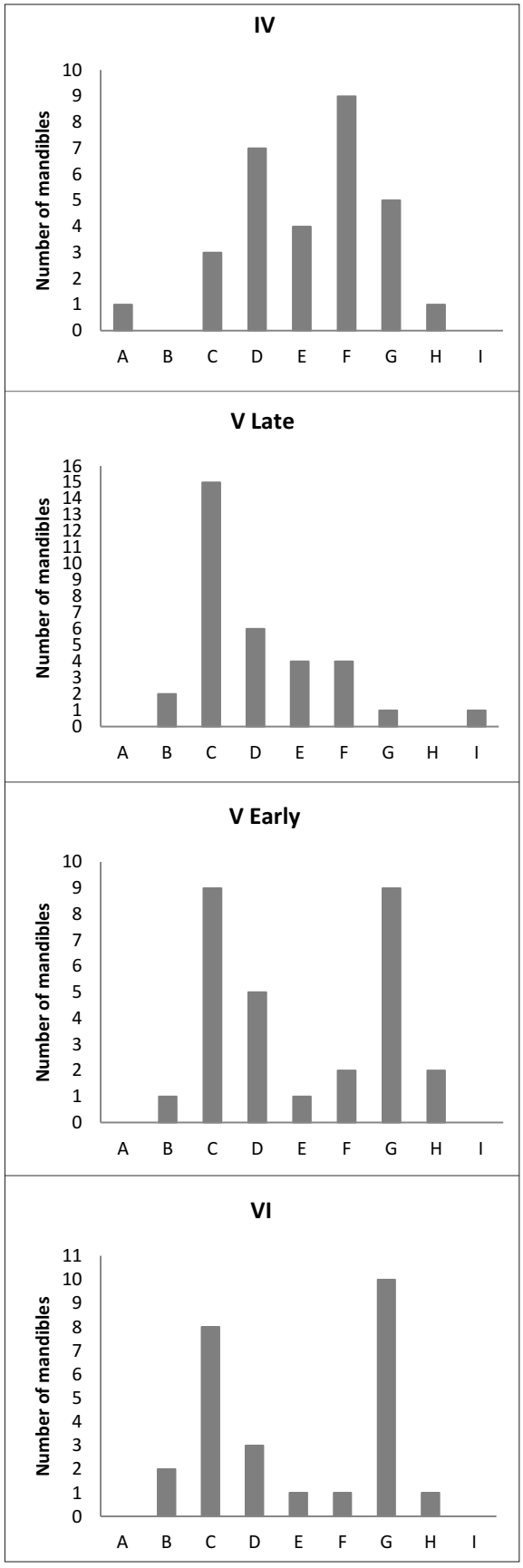


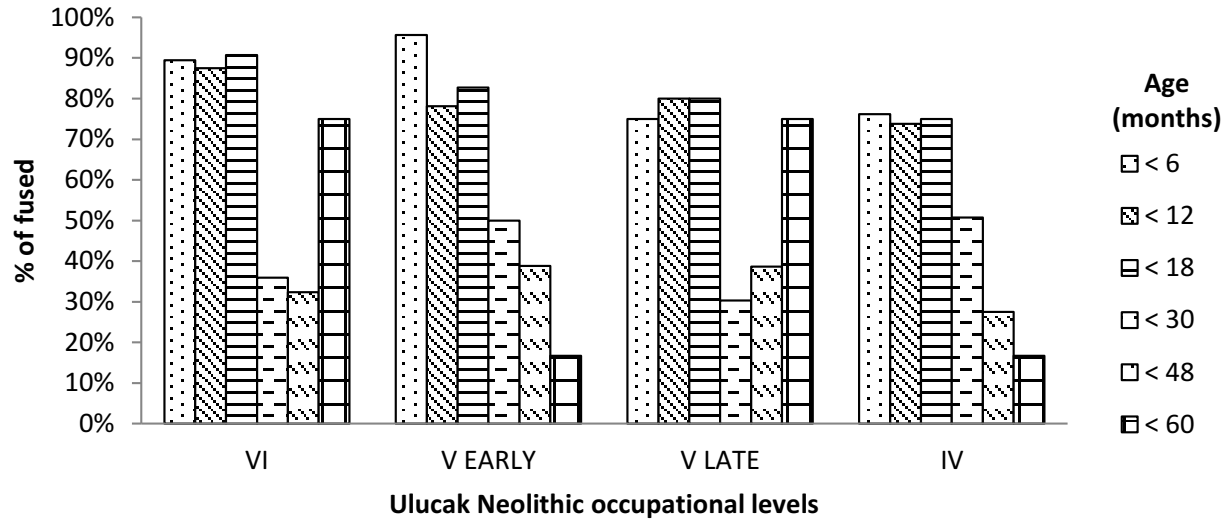
Fig. 8. Survivorship of sheep and goat by occupational level, based on tooth wear and eruption data (tooth wear classes follow Payne 1973; see table 5)

Payne (1973) stages	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*Total*
Level IV										
OVIS (sheep)										
L				2		2				4
R			1	3	2	2	1			9
CAPRA (goat)										
L				1		1	1			3
R							1			1
OVIS/CAPRA (sheep or goat)										
L				1	2		2			5
R	1		2			4		1		8
Level IV total	1		3	7	4	9	5	1		30
Level V Late										
OVIS (sheep)										
L		1	5		1	1				8
R			3	3			1			7
CAPRA (goat)										
L				1						1
LR				1						1
OVIS/CAPRA (sheep or goat)										
L		1	4	1	3	1				10
R			3			2			1	6
Level V Late total		2	15	6	4	4	1		1	33
Level V Early										
OVIS (sheep)										
L			2	2			1			5
R		1	3	2			2			8
CAPRA (goat)										
L			1	1						2
R							1			1
OVIS/CAPRA (sheep or goat)										
L			1			1	4	2		8
R			2		1	1	1			5
Level V Early total		1	9	5	1	2	9	2		29
Level VI										
OVIS (sheep)										
L		1	5				3	1		9
R		1	1	2		1	5			9
CAPRA (goat)										
L							2			2
R			1							1
OVIS/CAPRA (sheep or goat)										
L				1						1
R			1		1					2
Level VI total		2	8	3	1	1	10	1		26
Total	1	5	35	21	10	16	25	4	1	118

Table 5. Summary of OVIS/CAPRA *(sheep or goat) tooth wear data (following Payne 1973) by occupational level. A = 0–2 months, B = 2–6 months, C = 6–12 months, E = 2–3 years, F = 3–4 years, G = 4–6 years, I = 8–10 years*

animals between either six and 12 months (Grant Stage c) or four and six years of age (Grant Stage g). In Level V Late, the interest in keeping animals until four to six years old seems to have decreased dramatically (Grant Stage g and beyond), while earlier cullings began to target animals from one and a half to four years (Grant Stages d–e) rather evenly, with persisting emphasis on animals between six and 12 months of age. In Level IV, culling preferences shifted more concretely towards animals between one and a half and four years (Grant Stages d–f). Infant culling (Grant Stages a–b, the first six months) took place throughout the Neolithic, but these animals were never the focus of meat production. Throughout the sequence, few animals were kept until they were eight years old or older.

A total of 1,207 sheep and goat specimens provided epiphyseal fusion data. Specimens representing foetal and neonatal deaths are present in all levels in small amounts; their proportion in the NISP representing sheep and goat in each occupational level is given in the table accompanying fig. 9. Their proportion increases from 1% at the beginning of the settlement to 3% in Level IV. The epiphyseal fusion data indicate that less than 10% of lambs (younger than six months) were killed in Levels VI and V Early (fig. 9). Later on in Level V Late and IV, the proportion of animals that was culled before 18 months increased to c. 25%. Whilst in Level VI almost half the remaining individuals were being culled before 30 months, the proportion of animals culled before 30 months dropped rapidly in the later levels, first to c. 33%



	Age (months)	*Level VI*		*Level V Early*		*Level V Late*		*Level IV*	
	Perinatal specimens	21 (1%)		31 (2%)		31 (2%)		35 (3%)	
Epiphyses		*Fused*	*Unfused*	*Fused*	*Unfused*	*Fused*	*Unfused*	*Fused*	*Unfused*
Proximal radius	3–6	17	2	22	1	9	3	16	5
Distal humerus, pelvis, distal scapula	6–12	63	9	50	14	76	19	59	21
Proximal second phalanx, proximal first phalanx	12–18	49	5	24	5	20	5	39	13
Distal tibia, distal metapodia	18–30	41	73	32	32	20	46	33	32
Calcaneus tuber, proximal femur, proximal ulna, radius distal, proximal tibia, proximal tibia	30–48	32	67	26	41	29	46	25	66
Proximal humerus	48–60	3	1	1	5	3	1	1	5
	Total no. of observations	362		253		277		315	

Fig. 9. Survivorship of sheep and goats by occupational level based on long-bone fusion ratios (based on Zeder 2006)

in Level V Early and then down to 24% in the final Neolithic level (IV). The dental data also indicate a decrease in the frequency of juvenile cullings from Level VI to IV, with a clearer picture of a shift from a preference for juvenile animals (one to two years) to young adults (two to four years). In all levels, c. 30% of the animals seem to have been kept beyond two and a half years; animals which survived beyond four years existed at least in Levels VI and V Late. The fusion data probably underestimate the portion of the sheep and goat populations that survived beyond two and three years, due to the low preservation of late fusing elements.

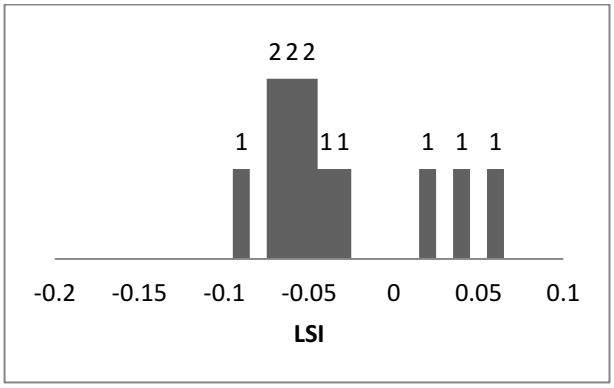
Few sufficiently well-preserved acetabulae (73 cases) were available to estimate sex ratios for sheep and goats. The large majority of sexable sheep and goat acetabulae was ascribed to female individuals (ten out of 11 observations in Level IV; 16 out of 21 observations in Level V Late; 18 out of 23 observations in Level V Early; and 14 out of 18 observations in Level VI). Notably, the proportions of female acetabulae in the oldest three chronological groups range between 76% and 78%, whereas in Level IV, the proportion of female acetabulae increases to 91%. However, because the sample sizes for each chronological subgroup are small, the significance of this increase should be approached with caution.

Based on the above data, it can be surmised that the keeping of sheep and goats focused primarily on meat production and herd security until c. 6500 BC, in a system which involved the culling of young males at prime age and keeping females as long as their reproduction rates were sufficiently high. The relatively low proportions of sheep and goats and the sustained proportions of cattle in Level V Late and IV suggest that some of the importance given to the production of meat from sheep and goats shifted towards pork production in younger levels. While the production of milk and fleece from sheep and goats cannot be ruled out during early periods of occupation at Neolithic Ulucak, the zooarchaeological record does not conform closely to existing lifetime product models (Payne 1973; Vigne, Helmer 2007). While slaughtering juvenile and prime-age individuals for meat is an expected pattern for the Neolithic, keeping animals up to six to eight years can be explained as a risk-buffering strategy in which old, prominent animals in the herd were not culled unless absolutely necessary. In such a management system, risk buffering herd stability, rather than strategies defined strictly by cost-benefit calculations, was an important motive (Redding 1984; Halstead 1992; Greenfield 2010). In Level V Early, risk-buffering mechanisms may have been consolidated by improvements in cattle breeding or the increase in pork production, leading to the elimination of keeping old animals in the herd. The kill-off patterns established throughout Levels VI and V Early began to change in Level V Late, from cullings focused on juvenile, prime-age and old individuals to animals between one and four years of age. In the final Neolithic phase, an entirely different exploitation strategy seems to have been adopted; one which targeted a broad range of products. In this new management system, where herd stability was not the most important concern, the focus was on culling a good portion of the individuals at about the time they reach maximum weight and keeping the rest of the herd for breeding purposes and for the exploitation of lifetime products, especially milk, until milk and meat gain began to decline (Vigne, Helmer 2007). The increase in the proportion of females based on sexed acetabulae in Level IV is likely to reflect a part of this strategy that involved keeping more females into older age. This method of exploitation targets meat gain and milk production enabled by keeping suckling lambs away from their mothers. This strategy of sheep and goat herding can be considered in a way more intensive; the intention to maximise protein yield and renew herds is evident rapidly, possibly derived from an incentive to feed a larger population. It should be underlined, however, that sheep and goat herding did not specialise in the production of any specific product.

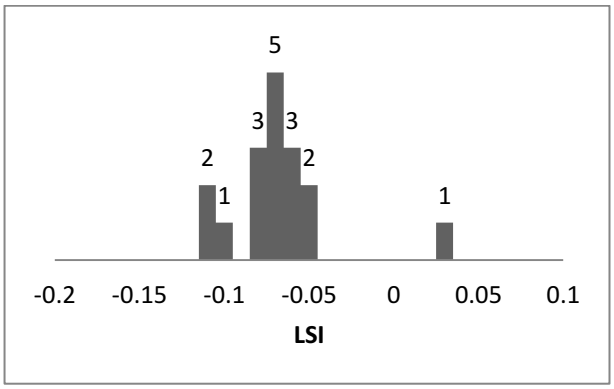
Pig

Pig (*SUS*) remains make up c. 15% of the specimen counts of the main food domesticates and c. 17% of their weight. The relative frequency of pig specimens among the remains of domestic food animals increases from c. 7% in Level VI to c. 22% in Level V Late, and drops slightly down to c. 17% in Level IV (fig. 3a). The WIS proportions of pig remains are largely compatible with the proportions based on NISP counts (fig. 3b).

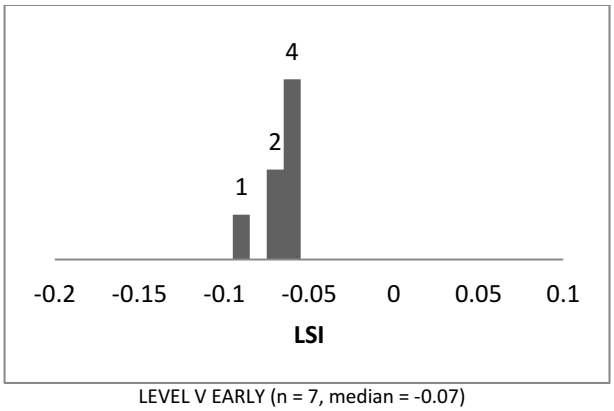
Due to the fact that most of the pigs at Neolithic Ulucak were culled before most of their bones were fused, only 41 *SUS/Sus scrofa* specimens provided suitable measurements for the LSI analysis. Despite the small sample size, logarithmic size indices show that morphologically domestic pigs comprised a large majority of the pigs consumed from the beginning of the settlement in Level VI (fig. 10). While a small number of specimens larger than the standard female wild boar is present at almost all levels, their identification as wild boar is questionable, again due to the problem of sample size. Although the two groups, one smaller and one larger than the standard, do not overlap, hinting at bimodality in size distributions, the presence of wild populations cannot be shown with certainty. The distribution of the LSI values of the Ulucak pigs overlaps nicely with the distribution of the group of small-sized pigs at Bademağacı (De Cupere et al. 2008) and falls almost completely



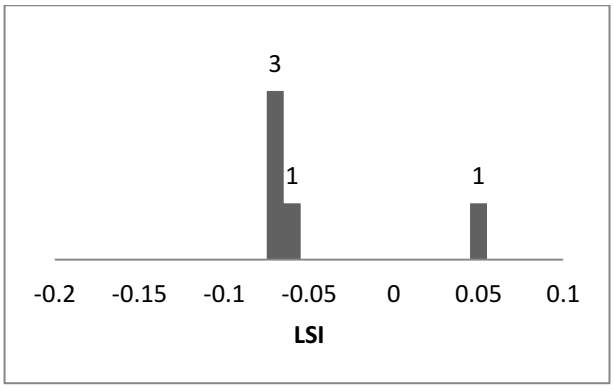
LEVEL IV (n = 12, median = -0.05)



LEVEL V LATE (n = 17, median = -0.07)



LEVEL V EARLY (n = 7, median = -0.07)



LEVEL VI (n = 5, median = -0.68)

Fig. 10. Logarithmic Size Index (= LSI) data for pigs by occupational level

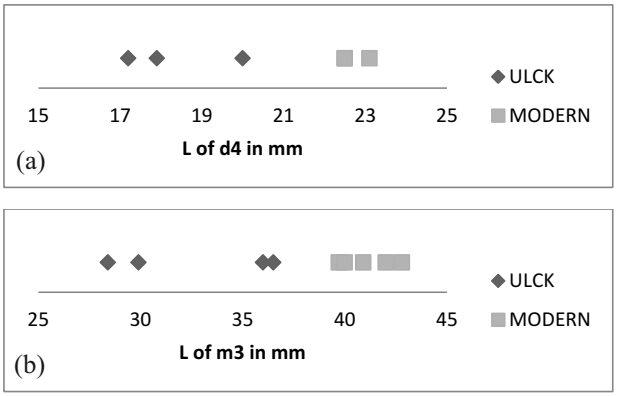


Fig. 11. Size comparisons between the fourth decidious (a) and third permanent (b) molars of pigs from Ulucak and modern wild boars from Turkey

outside the size range of wild boar from Pottery Neolithic Çatalhöyük (Russell, Martin 2005) and aceramic Aşıklı-höyük (Buitenhuis 1997). The interpretation of the large specimens as large males kept for breeding purposes is partly sustained by measurements of molar lengths (fig. 11). Tooth measurements can help distinguish wild and domestic pig remains and provide insights into the sexual composition of the individuals that were exploited (Payne, Bull 1988). The measured molar lengths from Neolithic Ulucak are substantially shorter than those of the modern wild Anatolian individuals investigated by Payne and Bull (1988). Although no prominent change in the logarithmic size indices is visible through time, the specimens from Level IV appear to be slightly larger. If these large specimens are to be interpreted as wild boar, this may imply an increase in boar hunting in Level IV. Such an increase can be linked to the increase in the proportion of fallow deer remains in the younger levels (see below).

Ageing data for pigs were generated from 36 mandibles (table 6) and 298 specimens that provided fusion data (fig. 12). The sample of mandibles is too small to break down into chronological clusters. Altogether they show that the majority of the individuals (67%) was culled before the completion of the first year, 19% were culled between one and two years of age, and a few (14%) lived until two to three years of age (table 6). Older animals with strongly-worn third molars (Grant Stage h–k) are absent from the studied sample, limiting the slaughter-age range for pigs to the first three years of life. Diachronically assessed fusion data largely correlate with the picture attained through the observations on pig tooth wear and eruption, indicating that the largest portion of the culling events took place early in life and few individuals survived up to 36 months or beyond (fig. 12). The peculiar mortality profile

Teeth in mandibles and Grant Stages represented	*< 12 months (d4 a–e; m1 U–e; m2 C–E)*	*12–24 months (d4 h; m2 a–f; p4 b; m2 c–f)*	*24–36 months (m3 a; m3 b; m3 d)*	*Total*
Level IV				
L	4		1	5
R	2	2	1	5
LR	2			2
Level V Late				
L	5	3	2	10
R	6			6
LR	2	1		3
Level V Early				
L	1		1	2
R	2			2
Level VI				
L		1		1
Total	24	7	5	36
% of total	67%	19%	14%	100%

Table 6. Pig tooth wear data (following Grant 1982) by occupational level

produced for Level VI based on bone fusion (fig. 12) is created by the unusually high representation of early fusing elements such as phalanges and metapodia in the small sample (28 observations) representing this occupational level. Bones of foetal/neonatal pigs and loose deciduous teeth are present in the deposits of Level VI, indicating that juvenile culling events were probably more frequent than indicated by the observations on long-bone fusion.

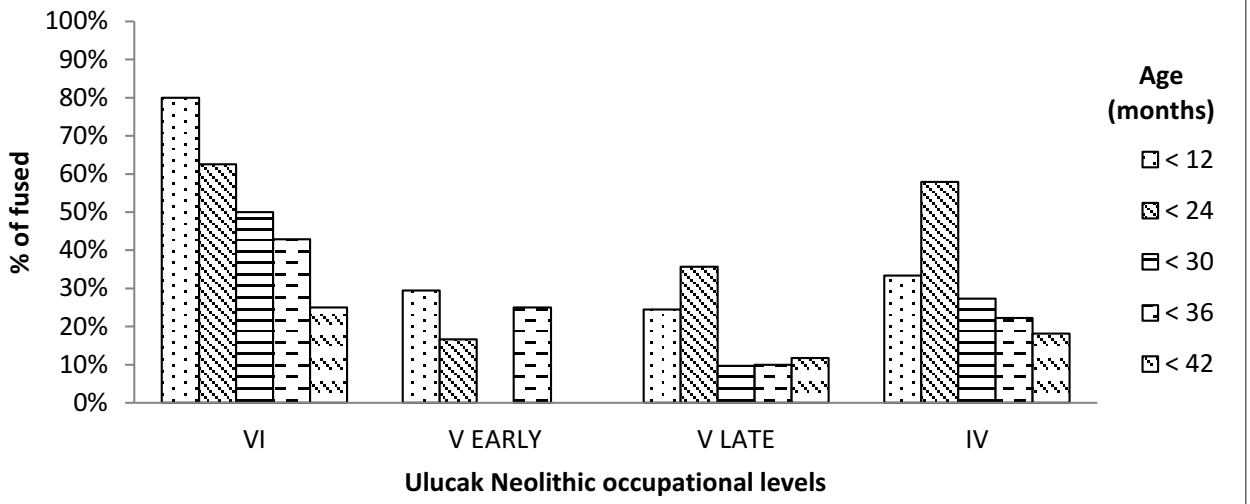
A very small number of pig canines provided information on sex. In Level VI, one female canine and two male canines were present; in level IV, three canines belonged to female individuals; and in Level V Early, three canines represented female individuals and one canine tooth belonged to a male. The number of cases is not sufficient to establish sex ratios of pig populations.

These data suggest that domestic pigs were present from the beginning of the settlement at Ulucak. Throughout the first 1,000 years of occupation, pork production became increasingly important. As expected, pigs were exclusively reared for their meat. Pig extremities were commonly processed for grease extraction, especially in Levels VI and V Early. Some of the pork may have been provided by hunting wild boar, but the scale of this activity was limited at most.

Exploitation of other faunal resources

While animal husbandry was the most important resource for the animal sector of the Neolithic economy of Ulucak, wild animals were also exploited (table 3, fig. 13). Logarithmic size indices do not provide clear evidence for the presence of aurochs and boar in the vicinity of Ulucak. Although the relatively greater presence of large specimens in Level IV may suggest that wild boar hunting became more prominent at this time, the evidence is scarce and ambiguous. Given that the anthracological evidence shows the presence of oak trees in the surroundings (Megaloudi 2005), providing a favourable habitat for boar populations, it is difficult to explain the absence or near absence of wild boar at the settlement. Wild goats (*Capra aegagrus*) were occasionally sought, probably at the rocky slopes surrounding the Kemalpaşa plain.

Terrestrial hunting activities mostly targeted deer (Cervidae) and, to a much lesser extent, hare (*Lepus europaeus*) (table 3, fig. 13). While red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) are present, while the remains of fallow deer (*Dama dama*) make up the largest component of Cervid finds. Remains include unworked and worked antlers (table 3), which may have been acquired as shed specimens in the



	Age (months)	*Level VI*		*Level V Early*		*Level V Late*		*Level IV*	
	Perinatal specimens	3 (1%)		0%		9 (3%)		15 (3%)	
Epiphyses		*Fused*	*Unfused*	*Fused*	*Unfused*	*Fused*	*Unfused*	*Fused*	*Unfused*
Distal scapula, pelvis, proximal radius, distal humerus	< 12	4	1	5	12	11	34	5	10
Distal tibia, proximal first and second phalanges	< 24	5	3	2	10	5	9	11	8
Distal metapodia, calcaneus tuber	< 30	2	2	0	13	3	28	6	16
Proximal and distal femur, proximal ulna	< 36	3	4	3	9	2	18	2	7
Proximal humerus, distal radius, proximal tibia	< 42	1	3	0	13	2	15	2	9
	Total no. of observations	28		67		127		76	

Fig. 12. Survivorship of pigs based on long-bone fusion ratios (based on Silver 1969)

wild. The proportion of deer remains in the archaeofaunal assemblage shows that, although fallow deer was exploited from the beginning of the seventh millennium BC, this activity started to gain importance in Level V Late (fig. 13) and later; in Level IV it provided c. 10% of the meat supply from major terrestrial mammals (fig. 13b). Although it could be argued that the increase in fallow deer is actually a product of a decrease in the number of domestic stocks, perhaps accompanied by a change in the role of animal husbandry in relation to crop cultivation, given the differential taphonomies of organic find groups and in the absence of density-controlled excavation records, such an argument could only lead to a circular discussion.

A similar increase in the proportion of fallow deer remains from the mid seventh millennium to the third millennium BC has been observed across the wider Aegean region and interpreted in several different ways, ranging from human management of the populations (Hubbard 1995) to game hunting by the rising élite (Hamilakis 2003). As for Ulucak, the current lack of related proxies (for example local palynological records) makes it difficult to identify the factors that influenced the relative increase in fallow deer remains. In the absence of local pre-seventh millennium BC faunal records, it is not even clear whether the fallow deer populations moved into west Anatolia in the seventh millennium BC or were present earlier in the Holocene

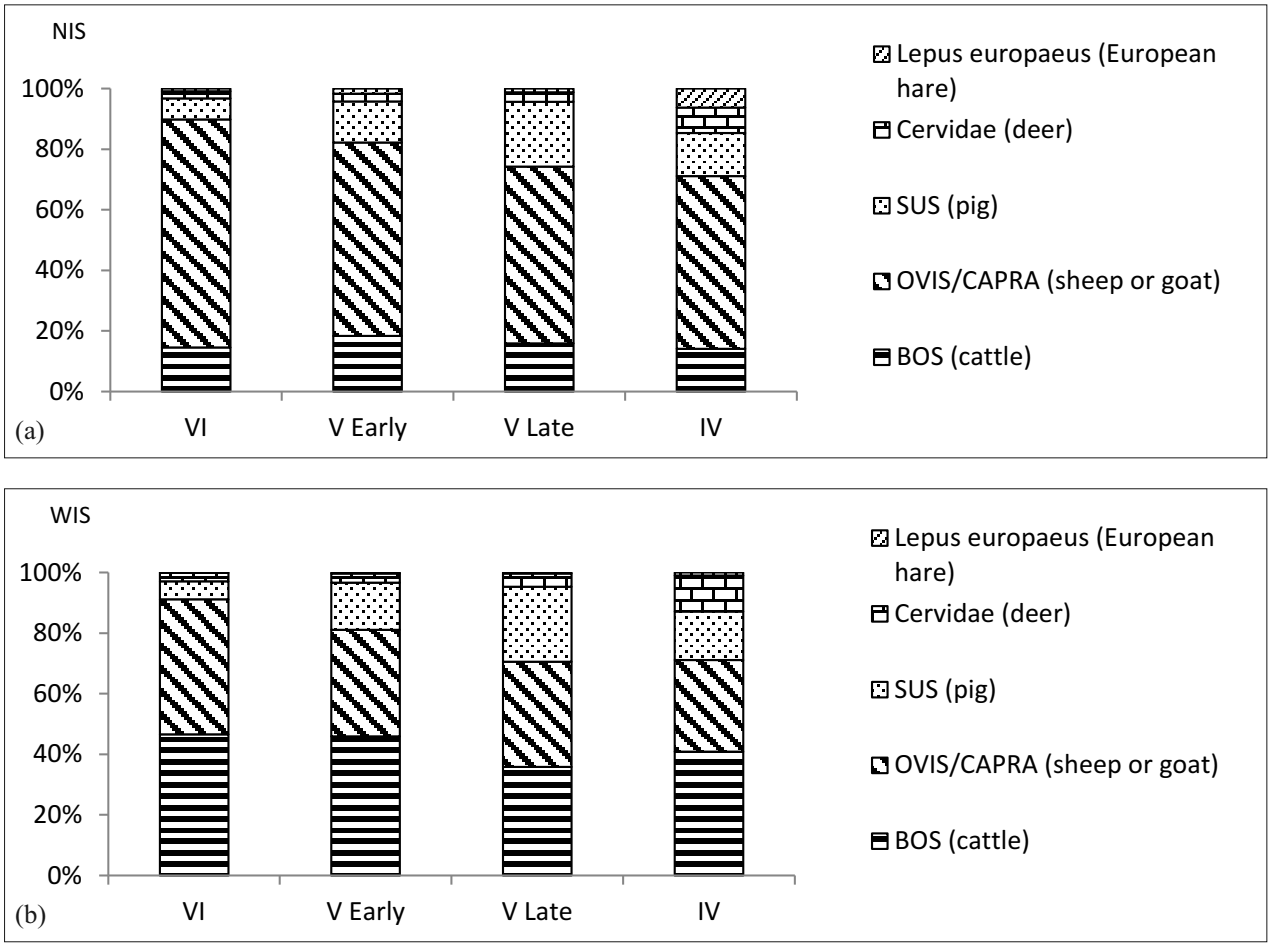


Fig. 13. Proportions of major food animals by occupational levels of Neolithic Ulucak based on NISP (a) and WIS (b) calculations

and Late Pleistocene. That fallow deer populations were introduced to Aegean islands like Crete in the early seventh millennium BC (Isaakidou 2004: 296–97) and to Rhodes during the six millennium BC (Masseti et al. 2006), probably in both cases from Anatolia, indicates that Neolithic communities were capable of affecting this species' 'natural' distribution. The nature of fallow deer exploitation is made somewhat clearer by the epiphyseal fusion data, which show clearly that fallow deer exploitation targeted mainly mature animals, indicating selective exploitation (fig. 14). Whether the fallow deer were captured from the wild or were somehow managed is a potential focus for future research.

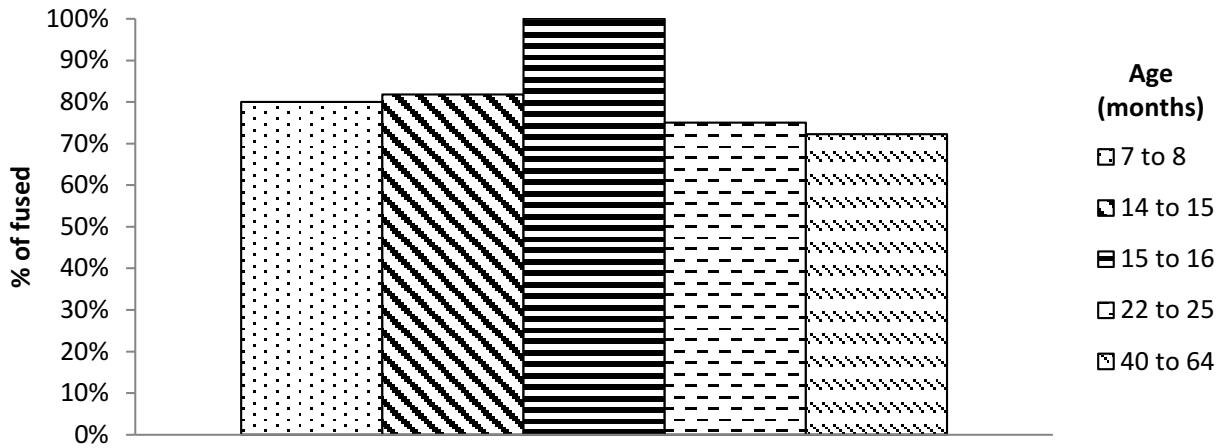
The increase in the proportion of European hare (*Lepus europaeus*), occurring in Level V and Level IV (fig. 13), can perhaps be proposed as supporting evidence for an environmental explanation for the increase in hunted animals. Both the European hare and fallow deer do well in open anthropogenic landscapes, threatening crop fields. The increase in hunting activities targeting these animals may have been born from the necessity to prevent them from intruding the crop fields, which presumably surrounded the settlement. In parallel, and perhaps unrelated to this development, hare and fallow deer populations may have increased as a result of deforestation induced by anthropogenic impact and/or the global climatic change that occurred around 6200 BC. Comprehensive palaeoenvironmental research in the vicinity of Ulucak should be able to verify or repudiate these inferences drawn from the zooarchaeological record.

Small to medium carnivores such as red fox (*Vulpes vulpes*), beech marten (*Martes foina*) and badger (*Meles meles*) are rare in the hand-collected assemblages; they may have been hunted for their fur or when they intruded the settlement in search for food. The leopard (*Panthera pardus*) in Level V Early (table 3) is a partial skeleton consisting of a calcaneus and a fifth metatarsal, i.e. elements of the hind foot. This find may represent the elimination of a one-time intruder or the trophy – probably the fur – of an occasional hunt at some distance from the settlement. The remains of small terrestrial

vertebrates such as rodents and reptiles probably represent disturbances in the archaeological soil matrix. There are no indications that these animals were exploited as a food resource.

Other than domestic cattle, sheep, goats and pigs, the Neolithic people of Ulucak also kept domestic dogs, whose finds are rare in the studied sample. Faunal remains with traces of carnivore (most likely dog) chewing are also rare throughout most of the sequence (table 2), although their proportion increases by almost threefold in Level IV. The scarcity of chew marks on bones, coupled with the rarity of dog remains, suggests that dogs were either not numerous or were not kept in the settlement. But this situation may have changed in Level V Late. Dogs sometimes occur as partial skeletons in various degrees of completeness in Levels IVb, Va and Vb. As these partial skeletons seem to have gone unnoticed during excavations, the precise nature of these articulated dog remains will remain unclear until the spatial analysis of the site is complete. There are no indications, such as butchery marks, that dog was part of the diet.

Birds and fish remains occur in minute numbers. Most of them are fragmentary and difficult to identify to lower taxa. Gilt-headed bream (*Sparus aurata*) is represented with a single dentary fragment in Level IV. Sea bream (Sparidae) is a marine fish that regularly enters lagoons and semi-closed bays. Its representation in inland Ulucak should be linked to other and plentiful evidence for the coastal and maritime connections of Neolithic Ulucak, such as the presence of large amounts of marine molluscs and Melian obsidian (Çilingiroğlu, Çevik forthcoming). On-going investigations of sieved deposits indicate that birds, fish and other small-sized vertebrates were much more numerous than has been observed in the hand-collected material. Bird, fish and mollusc remains will be discussed in future publications.



	Age (months)	*All Neolithic levels*	
	Perinatal specimens	0	
Epiphyses		*Fused*	*Unfused*
Proximal radius	7–8	4	1
Distal humerus	14–15	9	2
Distal scapula	15–16	9	0
Distal tibia	22–25	3	1
Proximal humerus, distal radius, femur, proximal tibia	40–64	13	5
	Total no. of observations	47	

*Fig. 14. Survivorship of fallow deer (*Dama dama*) by occupational level based on long-bone fusion ratios (modified after Carden, Hayden 2006). NISP = 72*

Discussion

The results presented above have important implications for our understanding of the establishment and development of early animal husbandry in central-west Anatolia, shedding much light on the role of the region in Neolithic expansions. While various lines of evidence for early animal husbandry (primarily 'macro-'zooarchaeological, but also palaeogenetic, biochemical and artefactual) are available from other important regions of Neolithisation, Ulucak is the only Neolithic site in central-western Anatolia where animal husbandry has been a focus of investigation. Although the absence of intra-regional comparative data prevents us from addressing diversity within the region, the zooarchaeological evidence from Ulucak, covering the earliest and longest radiocarbon dated Neolithic sequence west of the Lake District, represents an ideal anchorage for understanding Neolithic animal husbandry in the region and beyond. The results fill a zooarchaeological lacuna in the midst of a larger region bordered by the Lake District to the east (De Cupere, Duru 2003; De Cupere et al. 2008), Crete to the south (Isaakidou 2006), Thessaly to the west (Halstead, Jones 1980; von den Driesch 1987; Trantalidou 1990; Halstead 1992) and the Marmara region to the north (Buitenhuis 2008; Gourichon, Helmer 2008), enabling a clearer picture to emerge of the variety and consistency in animal husbandry practices across a vast area (fig. 1). This picture is discussed in what follows.

Results of taxonomic, osteometric and demographic analyses of the zooarchaeological material from Neolithic Ulucak indicate that all four of the initial domestic food animals were exploited in central-west Anatolia from the beginning of the seventh millennium BC.

Sheep and goat were the earliest domesticated food animals to appear west of the Taurus. By the beginning of the seventh millennium BC, sheep and goat herding was well established in central Anatolia and the Lake District (De Cupere, Duru 2003; Russell, Martin 2005; De Cupere et al. 2008; Arbuckle et al. 2009). Despite the presence of wild sheep and goat in both regions, there is no indication, neither from the Lake District nor from south-central Anatolia, that their domestication took place independently. Although independent sheep and goat domestication may have taken place at the late ninth millennium BC aceramic Aşıklıhöyük in Cappadocia further towards the east (Uerpmann 1979; Payne 1985; Buitenhuis 1997; 2002), this possibility is still subject to investigation (N. Polläth and H. Buitenhuis, personal communication). Recently, the 'aceramic' site of Suberde just southeast of the Lake District has been proposed as a locus for 'early caprine management' during the last quarter of the eighth millennium BC, but this interpretation is based on a small, unstratified faunal assemblage (Arbuckle 2008b), despite an earlier morphometric study that attested the domestic status of the sheep at the site (Uerpmann 1979). Moreover, both the presence of an aceramic layer and the radiocarbon dates from this site are currently matters of dispute (Çilingiroğlu 2009: 312).

Regardless of the debates on independent caprine domestication in Anatolia, the evidence from Ulucak shows that both domestic sheep and goat were present in the aceramic Neolithic settlements in distinct parts of Anatolia, including the western littoral. Other places where domestic sheep and goat remains have been found in aceramic Neolithic layers outside the Fertile Crescent are the remote Mediterranean islands of Crete and Cyprus (Isaakidou 2004; 2008; Vigne et al. 2011). While the dating and the geographical position of the early Cypriot domestic caprines place their origin in the Levant (Vigne et al. 2011), in light of recent evidence from Ulucak, western Anatolian herds could be proposed as a probable source of the domestic caprines that appeared at Knossos at the beginning of the seventh millennium BC. If the caprines of Knossos stemmed from the Anatolian mainland, however, this would raise the question as to why the movement of caprines from western Anatolia to Crete leapt over the smaller, less isolated islands in between, such as Rhodes. Although the Aegean islands were used for their natural resources, such as obsidian, at least from the Mesolithic (Laskaris et al. 2011), other than on Crete, permanent Neolithic settlements on true Aegean islands (i.e. islands which were not connected to the mainland during the Last Glacial sea level low stand) do not appear before the mid seventh millennium BC (Erdoğu 2003). On mainland Greece, domestic sheep and goat herds appear no earlier than 6400 BC, together with pottery technology (Reingruber 2005; Brami, Heyd 2011). The remarkable time-gap and differences in the associated cultural 'packages' between the earliest occurrences of sheep and goat herding in central-west Anatolia and on mainland Greece show that they were chronologically unrelated developments. Additionally, the initial appearance of sheep and goat herding in central-west Anatolia antedates their first occurrence in northwest Anatolia. Investigations at Ilıpınar and Menteşe date the earliest appearance of domestic sheep and goat in the Marmara region to the latter half of the seventh millennium BC (Buitenhuis 1995; 2008; Gourichon, Helmer 2008; Roodenberg 2008). But the date for this region may shift back to the early half of the seventh millennium BC with new data coming from Barçın Höyük (Gerritsen, Özbal 2011). Domestic sheep and goat herds do not seem to have reached Bulgaria any earlier than c. 6100 BC (Manhart 1998; Benecke 2006; Boyadzhiev 2006).

While domestic sheep and goat herds seem to have spread ubiquitously across Anatolia, Greece and Bulgaria in concurrence with the earliest appearance of a variety of other Neolithic elements, the adoption of cattle and pig herding seems to have followed more diverse trajectories in different parts of Anatolia. The earliest occurrences of domesticated cattle and pig in Anatolia are evidenced at Yumuktepe on the eastern coast of Mediterranean Turkey (Buitenhuis, Caneva 1998; Caneva 2002; Buitenhuis 2004) and Bademağacı and Höyücek in the Lake District (De Cupere, Duru 2003; De Cupere et al. 2008). At these sites, cattle and pig appear concurrently with sheep and goat, and pottery. While both domestic cattle and pig were absent from Çatalhöyük East (Russell, Martin 2005), domestic cattle were present at Erbaba just northwest of the Lake District towards the end of the seventh millennium BC (Arbuckle, Makarewicz 2009). The presence of domestic cattle and pig in Ulucak's early seventh millennium aceramic Level VI induces the idea that domesticated cattle and pig may have been more widespread in late aceramic Anatolia than has been previously attested. This possibility cannot be addressed in a satisfactory manner with the present evidence, because, for example, relevant zooarchaeological data are missing from the aceramic levels of the type-site of Hacılar in the Lake District (Mellaart 1964) and the bulk of the zooarchaeological sample from aceramic Suberde is lost (Arbuckle 2008b). On the other hand, while it can be postulated that the simultaneous appearance of the four food domesticates at aceramic Knossos and Ulucak (and perhaps Hacılar) may be related developments, it would be erroneous to suggest a link before the material culture ties between the aceramic phases are thoroughly studied.

Other than Crete and central-west Anatolia, domestic cattle and pig seem to emerge with the arrival of pottery in most areas west of central Anatolia, for example in the Lake District, mainland Greece and Bulgaria. The two regions where at least one of these taxa seems to have been adopted considerably later than the appearance of pottery are central and northwest Anatolia. In central Anatolia, both domestic cattle and pig appear more than half a millennium after the beginning of pottery production, at c. 6300 cal. BC (Russell, Martin 2005; Arbuckle, Makarewicz 2009). In northwest Anatolia, while domestic cattle is present from the beginning of the Neolithic, morphologically domestic pig is absent in settlements representing the earliest known Neolithic occupations, such as the late seventh millennium BC Ilıpınar X (Buitenhuis 2008), Fikirtepe (Boessneck, von den Driesch 1979) and Pendik (Çakırlar et al. in preparation). Despite these remarkable differences in the timing of the adoption of domestic cattle and pig in different regions across Anatolia, similar to the case of caprines, macro-zooarchaeological results do not suggest local domestication events for these animals (Boessneck, von den Driesch 1979; Buitenhuis 2008; Gourichon, Helmer 2008). But then again, this possibility is only just beginning to be explored using palaeogenetic tools (Edwards et al. 2007; Scheu 2011). Forthcoming palaeogenetic and zooarchaeological research, which will include the analyses of cattle and pig remains from Ulucak Level VI, may add considerable depth to the present picture of the initial stages of animal husbandry in Anatolia (G. Larson and J. Burger, personal communication).

In contrast to the variety involved in the initial adoption of farm animals, the emphasis placed on animal husbandry, as detected through calculations of the proportions of wild vs. domestic taxa in the zooarchaeological assemblages, is rather uniform both in Anatolia (Arbuckle 2006) and in southeast Europe (Benecke 2006; Cantuel et al. 2008). Although making accurate inter-regional comparisons in terms of the role of husbandry in overall protein production is encumbered by methodological differences in zooarchaeological data collection and presentation, it is still possible to form a general impression of the patterns of diversity and homogeneity in this regard. Similar to the situation at Ulucak, in regions where the four domesticates seem to have appeared simultaneously, regardless of the timing of their appearance, the remains of domestic animals dominate the vertebrate assemblages. This is true for both Anatolia, from Yumuktepe in the east (Buitenhuis, Caneva 1998; Caneva 2002; Buitenhuis 2004) to Ulucak in the west, and southeast Europe, including Knossos (Isaakidou 2004). In insular cases like Knossos, the absence of sizable game animals such as boar and deer is the obvious reason for the thin evidence for the exploitation of wild mammals. But on the mainland, the virtual absence of seventh millennium BC sites where hunting and herding were equally well represented is to be viewed as a consequence of cultural processes that involved the full implementation of animal husbandry. Even at settlements and regions where four-tiered animal husbandry was not fully adopted, such as Fikirtepe (Boessneck, von den Driesch 1979) and Çatalhöyük (Russell, Martin 2005), the animal sector of production relied heavily on herd keeping rather than the exploitation of wild fauna. Although a number of reasons (for example 'ethnicity', as proposed by Caneva 2002) can be suggested for this pattern, without further palaeoenvironmental data and detailed investigations targeting the Late Mesolithic occupations of the relevant regions, these suggestions are unlikely to go beyond speculation. On the other hand, the answer may be the obvious: these Neolithic communities comprised first and foremost farmers, who cultivated the land and

herded the animals not only because they had the know-how, but also because the codes of their social system necessitated them to do so, regardless of the choices they made in adopting various early food domesticates. It is noteworthy that the increase in the proportion of hunted animals towards the end of the seventh millennium at Ulucak is also observed in sites in southeast Europe, but at a later time period (von den Driesch 1987; Benecke 2006; Cantuel et al. 2008). The factors which drove this change are also difficult to address, again because of a lack of data.

The ways in which domestic food animals were managed and exploited once they were adopted are much less clear. Several of the questions which pertain to the management of herds, such as herd mobility, reproduction and foddering, are typically approached by analysing the various isotopic compositions of teeth and bone remains (Balasse, Tresset 2002; Bentley, Knipper 2005; Makarewicz, Tuross 2006). The application of such geochemical techniques to elucidate early herd management strategies in Anatolia has so far been limited to pilot studies conducted on caprine samples from Çatalhöyük and Aşıklıhöyük (Pearson et al. 2007; Henton et al. 2010). Questions involving the range of animal products that was exploited by the Neolithic farmers of Anatolia have been explored somewhat more extensively, commonly by the use of macro-zooarchaeological observations such as mortality profiles and pathologies (for example Russell, Martin 2005; Gourichon, Helmer 2008), but also by the application of a recently developed isotopic technique that enables ruminant milk to be distinguished from other archaeological lipid residues (Dudd, Evershed 1998; Evershed et al. 2008; Thissen et al. 2010).

Answers regarding the range of exploited animal products often reflect changes in theoretical approaches to the problem of when, where and how the exploitation of lifetime or 'secondary' products began. Until the end of the 20th century, most scholars maintained that early forms of domestic animals were biologically unsuitable for the exploitation of any resource other than primary products (meat, bone, hide) and that secondary products (milk, fleece, traction) were added to production systems at around 5000 BC or even later as part of a wider 'revolution' involving all aspects of life, technological and social, originating in southwest Asia (Flannery 1965; Sherratt 1981; Benecke 1994; Halstead 1996). Despite various indications for the use of lifetime products in eighth millennium BC sites in southwest Asia (for example Helmer 2000), discussions on the possibility of secondary product exploitation in Neolithic Anatolia were largely avoided until various zooarchaeological results were articulated in synthetic articles (Helmer et al. 2007; Vigne, Helmer 2007). For example, Russell and Martin (2005) interpret the results of the culling profile analysis of sheep and goats from Çatalhöyük 'to show typical management of sheep and goats for meat and herd reproduction', mentioning that milk and fleece may have been used as well at Çatalhöyük, without further elaboration. Stable isotopic evidence from lipid residues in Çatalhöyük pots later showed that dairy processing did take place at the Neolithic site, albeit probably not intensively (Evershed et al. 2008). Today, based on Evershed et al.'s influential *Nature* paper (2008), most archaeologists working in Anatolia consider istopic evidence from lipid residues as the only unequivocal evidence for dairy production (for example Thissen et al. 2010; Özdoğan 2011). Evershed et al's study (2008) also places northwest Anatolia under the spotlight as an early centre for milk processing and suggests that cow milk, rather than caprine, may have been the main source for dairy production in the region. This suggestion derives from the observation that cattle are represented in higher proportions in the faunal assemblages of Neolithic northwest Anatolia than in those of Neolithic sites towards the east. Mortality profiles, which are considered to be the most useful line of zooarchaeological evidence to identify the main goals of animal production (Helmer et al. 2007), were not used.

While mortality profiles can be biased by taphonomic processes and are open to interpretation, it is widely accepted that chronologically discernible mortality profiles generated from sufficiently sized samples can determine changes in exploitation strategies and suggest probable production goals. The greater difficulty arises when comparing the mortality profiles from different sites in an attempt to understand regional and inter-regional patterns of change in animal exploitation strategies, because different researchers use different methods to collect and present mortality data. For example, the preferred method to generate caprine mortality profiles at Ulucak and Çatalhöyük is that suggested by Payne (1973), whereas the method used by Boessneck and von den Driesch (1979) for the Fikirtepe fauna is not reproducible, at least not for researchers who are not familiar with the 'Munich school'. These two methods are largely incompatible with one another, preventing accurate data integration.

Despite these methodological and theoretical problems, a few brief suggestions can be made about the probable patterns of secondary product utilisation in Anatolia. In the Lake District and central-west Anatolia, represented respectively by Bademağacı and Ulucak, the courses of sheep and goat exploitation seem to have developed along similar trajectories, and not dissimilarly from that observed for central Anatolia. In central-west

Anatolia and the Lake District, sheep and goat exploitation seems to have evolved from meat production based primarily on culling juvenile and young animals for their meat to milk production secured by keeping animals into older age (De Cupere et al. 2008: table 7). At least at Ulucak, the earlier form of exploitation seems to have involved keeping animals into very old age, probably as a risk-buffering strategy. Sample sizes from neither region allow for separate evaluations of sheep and goat use. In central Anatolia, on the other hand, larger samples allow for separate observations about sheep and goats. Arbuckle et al. (2009) postulate that sheep were exploited for their meat and perhaps milk from the beginning of the Neolithic in central Anatolia, and that this system shifted towards a more intensified lamb and milk production sometime during the second half of the seventh millennium BC. For goats, they propose that a small-scale mixed exploitation system may have been in existence from the beginning of the Neolithic in the region (Arbuckle et al. 2009).

The methodological problems that arise from differential presentation and interpretation of caprine mortality profiles are true for cattle as well. In addition, sample sizes for cattle are ubiquitously smaller than those for caprines in Neolithic Anatolia and southeast Europe, which further hampers interpretation. Fusion data suggest that Neolithic communities in both central-west Anatolia and the Lake District may have started exploiting cattle for their milk towards the end of the seventh millennium BC (De Cupere et al. 2008). For the use of cattle as labour, possibly in land tilting, stress-related pathologies on cattle bones have been presented as evidence in two isolated cases (Isaakidou 2006; Gourichon, Helmer 2008). Pathological cattle bones found at the seventh millennium BC site of Menteşe located in the southeast Marmara region appear to display Stage 2–3 pathologies (based on De Cupere et al.'s scheme [2000]) which can be ascribed to working cattle (Gourichon, Helmer 2008). The pathological cattle bones found at Early Neolithic Knossos on Crete constitute the second case for which it is argued that these were signatures of the use of cattle in traction (Isaakidou 2004; 2006). These arguments, however, are not supported by reproducible data, i.e. numerically-expressed modification stages compatible with Bartosiewicz et al. 1997. At other relevant sites, stress-related pathological modifications on domestic cattle extremities are either absent or not mentioned. Such modifications are present on very few cattle specimens at Neolithic Ulucak and they are not severe enough to make a firm basis for a traction argument. Accordingly, it should be held that ample evidence for the use of cattle in traction in Neolithic Anatolia and southeast Europe is absent.

Conclusions

The Neolithic way of life continued in Anatolia for almost 2,000 years before it reached mainland southeast Europe. How the Neolithic way of life emerged and evolved in diverse parts of this vast region is only just beginning to be understood (Brami, Heyd 2011; Düring 2011a; Özdoğan 2011). The zooarchaeological data from Neolithic Ulucak provide vital information regarding how and when animal husbandry began and evolved at the western end of the Anatolian frontier, partially filling a gap in the knowledge regarding this intrinsic aspect of becoming and being Neolithic in the wider eastern Mediterranean area.

In a nutshell, the data indicate that the four-tiered husbandry system that emerged together with the establishment of aceramic Ulucak at the beginning of the seventh millennium BC went through substantial transformations in the younger phases of the Neolithic, with relatively more emphasis placed on pork and towards milk exploitation from caprines and possibly from cattle. This information, demonstrating that full-scale animal husbandry was practised in central-west Anatolia almost half a millennium prior to its appearance on the western side of the Aegean, allows central-west Anatolia to be placed at the centre of debates concerning the origins of animal husbandry in southeast Europe. The zooarchaeological data from Ulucak also indicate that another thread of the transformations concerning the role of animal husbandry in Neolithic lifeways involved an apparent increase in the exploitation of wild faunal resources towards the end of the Neolithic. Amalgamated data from the surrounding regions indicate that while these developments were not unparalleled in the greater frontier of westward Neolithisation, a variety of unique developmental trajectories were experienced in distinct areas.

Future zooarchaeological data from continuing excavations at Ulucak and other Neolithic sites will certainly shed more light on the diversity of animal husbandry innovations in the distinct regions of the west Anatolian frontier and provide much needed aid to understanding the ways in which technical know-how was negotiated between diverse cultural groups and through successive generations.

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Bibliography

Arbuckle, B. 2006: *The Evolution of Sheep and Goat Pastoralism and Social Complexity in Central Anatolia*. PhD thesis, Harvard University

— 2008a: 'Caprine exploitation at Erbaba Höyük: a Pottery Neolithic village in central Anatolia' in L. Gourichon, E. Vila (eds), *Zooarchaeology of Southwestern Asia and Adjacent Areas* 8. Paris: 345–65

— 2008b: 'Revisiting Neolithic caprine exploitation at Suberde, Turkey' *Journal of Field Archaeology* 33: 219–36

Arbuckle, B., Erek, M. 2010: 'Late Epipalaeolithic hunters of the central Taurus: faunal remains from Direkli cave, Kahramanmaraş, Turkey' *Journal of Osteoarchaeology*: doi 10.1002/oa.1230

Arbuckle, B., Makarewicz, C. 2009: 'The early management of cattle (*Bos taurus*) in Neolithic central Anatolia' *Antiquity* 83: 669–86

Arbuckle, B., Öztan, A., Gülçur, S. 2009: 'The evolution of sheep and goat husbandry in central Anatolia' *Anthropozoologica* 44.1: 129–57

Atıcı, L. 2011: *Before the Revolution: Epipalaeolithic Subsistence in the Western Taurus Mountains, Turkey* (British Archaeological Reports 2251). Oxford

Balasse, M. 2003: 'Keeping the young alive to stimulate milk production? Differences between cattle and small stock' *Anthropozoologica* 7: 3–10

Balasse, M., Tresset, A. 2002: 'Early weaning of Neolithic domestic cattle (Bercy, France) revealed by intra-tooth variation in nitrogen isotope ratios' *Journal of Archaeological Science* 29: 853–59

Bartosiewicz, L., Van Neer, W., Lentacker, A. 1997: *Draught Cattle: Their Osteological Identification and History*. Tervuren

Benecke, N. 1994: *Der Mensch und seine Haustiere, die Geschichte einer Jahrtausendealten Beziehung*. Stuttgart

— 2006: 'Animal husbandry and hunting in the Early Neolithic of south-east Europe – a review' in I. Gatsov, H. Schwarzberg (eds), *Aegean-Marmara-Black Sea: The Present State of Research on the Early Neolithic*. Langenweissbach: 175–86

Bentley, R., Knipper, C. 2005: 'Geographical patterns in biologically available strontium, carbon and oxygen isotope signatures in prehistoric SW Germany' *Archaeometry* 47.3: 629–44

Boessneck, J. 1962: 'Die Tierreste aus Argissa Magula vom präkeramischen Neolithikum bis zum mittleren Bronzezeit' in V. Milojcic, J. Boessneck, M. Hopf (eds), *Die Deutschen Ausgrabungen auf der Argissa Magula in Thessalien* 1. *Das präkeramische Neolithikum sowie die Tier- und Pflanzenreste*. Bonn: 27–99

— 1992: 'Besprechung der Tierknochen- und Molluskenreste von Hassek Höyük' in M.R. Behm-Blancke (ed.), *Hassek Höyük, Naturwissenschaftliche Untersuchungen und Lithische Industrie*. Tübingen: 58–74

Boessneck, J., Müller, H.H., Teichert, M. 1964: *Osteologische Unterscheidungsmerkmale zwischen Schaf (Ovis aries Linné) und Ziege (Capra hircus Linné)* (Kühn-Archiv 78 H. 1–2). Munich

Boessneck, J., von den Driesch, A. 1979: *Die Tierknochenfunde aus der Neolithischen Siedlung auf dem Fikirtepe bei Kadıköy am Marmarameer*. Munich

Bollongino, R., Elsner, J., Vigne, J.-D., Burger, J. 2008: 'Y-SNPs do not indicate hybridisation between European aurochs and domestic cattle' *PLoS ONE* 3.10: e3418, doi 10.1371/journal.pone.0003418

Boyadzhiev, Y. 2006: 'The role of absolute chronology in clarifying the Neolithization of the eastern half of the Balkan peninsula' in I. Gatsov, H. Schwarzberg (eds), *Aegean-Marmara-Black Sea: The Present State of Research on the Early Neolithic*. Langenweissbach: 7–14

Brami, M., Heyd, V. 2011: 'The origins of Europe's first farmers: the role of Hacılar and western Anatolia, fifty years on' *Prähistorische Zeitschrift* 86: 165–206

Buitenhuis, H. 1995: 'The faunal remains' in J. Roodenberg (ed.), *The Ilıpınar Excavations* 1*: Five Seasons of Fieldwork in NW Anatolia 1987–91*. Leiden, Istanbul: 151–57

— 1997: 'Aşıklı Höyük: a "protodomestication" site' *Anthropozoologica* 25/26: 655–62

— 2002: 'Two annotated charts of the state of archaeozoological research in central and western Anatolia, 10,000–5000 cal BC' in F. Gerard, L. Thissen (eds), *The Neolithic of Central Anatolia: Internal Developments and External Relations During the 9th–6th Millennia Cal. BC*. Istanbul: 217–18

— 2004: 'The importance of Yumuktepe in the origin and spread of animal domestication' in I. Caneva, V. Sevin (eds), *Mersin-Yumuktepe: A Reappraisal*. Lecce: 163–68

— 2008: 'Ilıpınar: the faunal remains from the Late Neolithic and Early Chalcolithic levels' in E. Vila, L. Gourichon, A. Choyke, H. Buitenhuis (eds), *Zooarchaeology of the Near East* 8*: Proceedings of the Eighth International Symposium on the Zooarchaeology of Southwestern Asia and Adjacent Areas*. Lyon: 299–322

Buitenhuis, H., Caneva, I. 1998: 'Early animal breeding in southeastern Anatolia: Mersin-Yumuktepe' in P. Anreiter, L. Bartosiewicz, E. Jerem, W. Weid (eds), *Man and the Animal World* (Studies in Archaeology, Archaeolingua 8). Budapest: 121–30

Çakırlar, C., von den Driesch, A., Obermaier, H. in preparation: 'Reassessing Neolithic subsistence in Istanbul with new evidence from Pendik'

Caneva, I. 2002: 'Ethnicity as a form of relationship between Neolithic Cilicia and central Anatolia' in F. Gerard, L. Thissen (eds), *The Neolithic of Central Anatolia: Internal Developments and External Relations During the 9th–6th Millennia Cal. BC*. Istanbul: 119–30

Cantuel, J., Gardeisen, A., Renard, J. 2008: 'L'exploitation de la faune durant le Néolithique dans le bassin Égéen' in E. Vila, L. Gourichon, A. Choyke, H. Buitenhuis (eds), *Zooarchaeology of the Near East* 8*: Proceedings of the Eighth International Symposium on the Zooarchaeology of Southwestern Asia and Adjacent Areas*. Lyon: 279–98

Carden, R., Hayden, T. 2006: 'Epiphyseal fusion in postcranial skeletons as an indicator of age at death of European fallow deer (*Dama dama*, Linnaeus, 1758)' in D. Ruscillo (ed.), *Recent Advances in Ageing and Sexing Animal Bones*. Oxford: 227–36

Çilingiroğlu, A., Abay, E. (eds) 2005: 'Ulucak Höyük excavations: new results' *Mediterranean Archaeology and Archaeometry* 5.3: 5–21

Çilingiroğlu, A., Çilingiroğlu, Ç. 2007: 'Ulucak' in M. Özdoğan, N. Başgelen (eds), *Türkiye'de Neolitik Dönem: Yeni Kazılar, Yeni Bulgular*. Istanbul: 361–72

Çilingiroğlu, A., Derin, Z., Abay, E., Sağlamtimur, H., Kayan, I. 2004: *Ulucak Höyük: Excavations Conducted between 1995–2002*. Leuven

Çilingiroğlu, Ç. 2009: *Central-west Anatolia at the end of the 7th and beginning of the 6th Millennium BCE in the Light of Pottery from Ulucak (Izmir)*. PhD thesis, Eberhard Karls Universität, Tübingen

Çilingiroğlu, Ç. 2010: 'The appearance of impressed pottery in the Neolithic Aegean and its implications for maritime networks in the eastern Mediterranean' *Turkish Academy of Sciences Journal of Archaeology* 13: 9–22

Çilingiroğlu, Ç., Çevik, Ö. forthcoming: 'Ulucak's earliest inhabitants' in D. Borić, M. Gurova, P. Miracle (eds), *Identities of the First Neolithic Communities in the Balkans*. Oxford

Clare, L., Rohling, E.J., Weninger, B., Hilpert, J. 2008: 'Warfare in Late Neolithic/Early Chalcolithic Psidia, southwestern Turkey. Climate induced social unrest in the late 7th millennium BC' *Documenta Praehistorica* 35: 65–92

Conolly, J., Colledge, S., Dobney, K., Vigne, J.-D., Peters, J., Stopp, B., Manning, K., Shennan, S. 2011: 'Meta-analysis of zooarchaeological data from SW Asia and SE Europe provides insight into the origins and spread of animal husbandry' *Journal of Archaeological Science* 38.3: 538–45

Davis, S. 1987: *The Archaeology of Animals*. London

De Cupere, B., Duru, R. 2003: 'Faunal remains from Neolithic Höyücek and the presence of early domestic cattle in Anatolia' *Paléorient* 29: 107–20

De Cupere, B., Duru, R., Umurtak, G. 2008: 'Animal husbandry at the Early Neolithic to Early Bronze Age site of Bademağacı (Antalya province, SW Turkey): evidence from the faunal remains' in E. Vila, L. Gourichon, A. Choyke, H. Buitenhuis (eds), *Zooarchaeology of the Near East* 8*: Proceedings of the Eighth International Symposium on the Zooarchaeology of Southwestern Asia and Adjacent Areas*. Lyon: 367–405

De Cupere, B., Lentacker, A., Van Neer, W., Waelkens, M., Verslype, L. 2000: 'Osteological evidence for the draught exploitation of cattle: first applications of a new methodology' *International Journal of Osteoarchaeology* 10: 254–67

Degerbøl, M., Fredskild, B., 1970: *The Urus (*Bos primigenius *Bojanus) and Neolithic Domesticated Cattle (*Bos taurus domesticus *Linné) in Denmark, with a Revision of* Bos *Remains from the Kitchen Middens: Zoological and Palynological Investigations* (Det Kongelige Danske Videnskabernes Selskab Biologiske Skrifter 17.1). Copenhagen

Derin, Z. 2007: 'Yeşilova Höyüğü' in M. Özdoğan, N. Başgelen (eds), *Türkiye'de Neolitik Dönem: Yeni Kazılar, Yeni Bulgular.* Istanbul: 377–84

Dudd, S., Evershed, R. 1998: 'Direct demonstration of milk as an element of archaeological economies' *Science* 282: 1478–81

Düring, B. 2011a: *Prehistory of Asia Minor*. Cambridge

— 2011b: 'Millennia in the middle? Reconsidering the Chalcolithic of Asia Minor' in S. Steadman, G. McMahon (eds), *Oxford Handbook of Anatolian Studies, 8000–323 BC*. Oxford: 796–812

Duru, R. 2008: *M.Ö. 8000'den M.Ö. 2000'e Burdur-Antalya Bölgesinin Altıbin Yılı*. Istanbul

Eastwood, W.J., Roberts, N., Lamb, H.F., Tibby, J.C. 1999: 'Holocene environmental change in southwest Turkey: palaeoecological record of lake and catchment-related changes' *Quaternary Science Reviews* 18: 671–95

Edwards, C.J., Bollongino, R., Scheu, A., Chamberlain, A., Tresset, A., Vigne, J.-D., Baird J.-F., Larson, G., Ho, S.Y.W., Heupink, T.H., Shapiro, B., Freeman, A.R., Thomas, M.G., Arbogast, R.M., Arndt, B., Bartosiewicz, L., Benecke, N., Budja, M., Chaix, L., Choyke, A.M., Coqueugniot, E., Döhle, H.-J., Göldner, H., Hartz, S., Helmer, D., Herzig, B., Hongo, H., Mashkour, M., Özdoğan, M., Pucher, E., Roth, G., Schade-Lindig, S., Schmölke, U., Shulting, R.J., Stephan, E., Uerpmann, H.-P., Vörös, I., Voytek, B., Bradley, D.G., Burger, J. 2007: 'Mitochondrial DNA analysis shows a Near Eastern Neolithic origin for domestic cattle and no indication of domestication of European aurochs' *Proceedings of the Royal Society, Biological Sciences* 274.1616: 1377–85

Erdoğu, B. 2003: 'Visualizing the Neolithic landscape: the early settled communities in western Anatolia and eastern Aegean islands' *Journal of European Archaeology* 6.1: 7–23

Evershed, R.P., Payne, S., Sheratt, A.G., Coolidge, J., Urem-Kotsu, D., Kotsakis, K., Özdoğan, M., Özdoğan, A., Nieuwenhuyse, O., Akkermans, P.M.M.G., Bailey, D., Andeescu, R.-R., Campbell, S., Farid, S., Hodder, I., Yalman, N., Özbaşaran, M., Bıçakçı, E., Garfinkel, Y., Levy, T., Burton, M.M. 2008: 'Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding' *Nature* 455: 528–31

Flannery, K. 1965: 'The ecology of early food production in Mesopotamia' *Science* 147.3663: 1247–56

Gerritsen, F., Özbal, R. 2011: 'Barçın Höyük excavations 2011' *Netherlands Institute in Turkey Newsletter* 2011.2: 4

Gillis, R., Chaix, L., Vigne, J.-D. 2011: 'An assessment of morphological criteria for discriminating sheep and goat mandibles in a large prehistoric archaeological assemblage (Kerma, Sudan)' *Journal of Archaeological Science* 38.9: 2324–39

Götherström, A., Anderung, C., Hellborg, L., Rengert, E., Smith, C., Bradley, D.G., Ellegren, H. 2005: 'Cattle domestication in the Near East was followed by hybridization with aurochs bulls in Europe' *Proceedings of the Royal Society, Biological Sciences* 272.1579: 2345–51

Gourichon, L., Helmer, D. 2008: 'Etude de la Faune Neolithique de Menteşe' in J. Roodenberg, S. Alpaslan-Roodenberg (eds), *Life and Death in a Prehistoric Settlement in Northwest Anatolia: The Ilıpınar Excavations* 3. Leiden: 435–48

Grant, A. 1982: 'The use of tooth wear as a guide to the age of domestic ungulates' in B. Wilson, C. Grigson, S. Payne S. (eds), *Ageing and Sexing Animal Bones from Archaeological Sites* (British Archaeological Reports International Series 109). Oxford: 91–107

Greenfield, H. 2010: 'The secondary products revolution: the past, present and the future' *World Archaeology* 42.1: 29–54

Grigson, C. 1982: 'Sex and age determination of some bones and teeth of domestic cattle: a review of the literature' in B. Wilson, C. Grigson, P. Payne (eds), *Ageing and Sexing Animal Bones from Archaeological Sites* (British Archaeological Reports International Series 109). Oxford: 7–24

— 1989: 'Size and sex: evidence for the domestication of cattle in the Near East' in A. Milles, D. Williams, N. Gardner (eds), *The Beginnings of Agriculture* (British Archaeological Reports International Series 496). Oxford: 77–109

Habermehl, K.-H. 1975: *Die Altersbestimmung bei Haus- und Labortieren*. Berlin, Hamburg

Halstead, P. 1992: 'From reciprocity to redistribution: modelling the exchange of livestock in Neolithic Greece' *Anthropozoologica* 7: 63–75

— 1996: 'Pastoralism or household herding? Problems of scale or specialization in early Greek animal husbandry' *World Archaeology* 28: 20–42

Halstead, P., Collins, P., Isaakidou, V. 2002: 'Sorting the sheep from the goats: morphological distinctions between the mandibles and mandibular teeth of adult *Ovis* and *Capra*' *Journal of Archaeological Science* 29: 545–53

Halstead, P., Jones, G. 1980: 'Early Neolithic economy in Thessaly: some evidence from excavations at Prodromos' *Anthropologika* 1: 93–117

Hamilakis, Y. 2003: 'The sacred geography of hunting: wild animals, social power and gender in early farming societies' in E. Kotjabopoulou, Y. Hamilakis, P. Halstead, C. Gamble, P. Elefanti (eds), *Zooarchaeology in Greece: Recent Advances*. London: 239–47

Helmer, D. 2000: 'Étude de la faune mammalienne d'El Kowm 2 (Syrie)' in D. Stordeur (ed.), *Une île dans le Désert: El Kowm 2 (Néolithique précéramique, 8,000–7,500 BP Syrie)*. Paris: 233–64

Helmer, D., Gourichon, L., Vila, E. 2007: 'The development of the exploitation of products from *Capra* and *Ovis* (meat, milk and fleeces) from the PPNB to the Early Bronze in the northern Near East (8700 to 2000 BC cal.)' *Anthropozoologica* 42: 41–69

Hemmer, H. 1990: *Domestication.* Cambridge

Henton, E., Meier-Augenstein, W., Kemp, H.F. 2010: 'The use of oxygen isotopes in sheep molars to investigate past herding practices at the Neolithic settlement of Çatalhöyük, central Anatolia' *Archaeometry* 52: 429–49

Hole, F., Flannery, K.V., Neely, J.A. 1969: *Prehistory and Human Ecology of the Deh Luran Plain* (Memoirs of the Museum of Anthropology 1). Ann Arbor

Hongo, H., Meadow, R. 2000: 'Faunal remains from Prepottery Neolithic levels at Çayönü, southeastern Turkey: a preliminary report focusing on pigs (Sus *sp.*)' in M. Mashkour, A.M. Choyke, H. Buitenhuis, F. Poplin (eds), *Archaeozoology of Southwest Asia*. Groningen: 121–40

Hubbard, R.N.L.B. 1995: 'Fallow deer in prehistoric Greece, and the analogy between faunal spectra and pollen analyses' *Antiquity*: 527–38

Isaakidou, V. 2004: '*Bones from the Labyrinth: Faunal Evidence for the Management and Consumption of Animals at Neolithic and Bronze Age Knossos, Crete*. PhD thesis, University College London

— 2006: 'Ploughing with cows: Knossos and the "secondary products revolution"' in D. Serjeantson, D. Field (eds), *Animals in the Neolithic of Britain and Europe*. Oxford: 95–112

— 2008: '"The fauna and economy of Neolithic Knossos" revisited' in V. Isaakidou, P. Tomkins (eds), *Escaping the Labyrinth: The Cretan Neolithic in Context*. Sheffield: 95–112

Kayan, I. 1999: 'Kemalpaşa çevresinde geçmişten günümüze arazi kullanımı ve günümüzdeki sorunlar' *Kemalpaşa Kültür ve Çevre Sempozyumu Bildiriler Kitabı*. Izmir: 1–16

Larson, G., Albarella, U., Dobney, K., Rowley-Conwy, P., Schibler, J., Tresset, A., Vigne, J.-D., Edwards, C.-J., Schlumbaum, A., Dinu, A., Balacsescu, A., Dolman, G., Tagliacozzo, A., Manaseryan, A., Miracle, P., van Wijngaarden-Bakker, L., Masseti, M., Bradley, D.G., Cooper, A. 2007: 'Ancient DNA, pig domestication, and the spread of the Neolithic into Europe' *Proceedings of the National Academy of Sciences* 104.39: 15276–81

Laskaris, N., Sampson, A., Mavridis, F., Liritzis, I. 2011: 'Late Pleistocene/Early Holocene seafaring in the Aegean: new obsidian hydration dates with the SIMS-SS method' *Journal of Archaeological Science* 38.9: 2475–79

Lichter, C., Meriç, R. 2007: 'Dedecik-Heybelitepe' in M. Özdoğan, N. Başgelen (eds), *Türkiye'de Neolitik Dönem: Yeni Kazılar, Yeni Bulgular*. Istanbul: 385–86

Lyman, R.L. 1994: *Vertebrate Taphonomy*. Cambridge

— 2008: *Quantitative Palaeozoology*. Cambridge

Makarewicz, C., Tuross, N. 2006: 'Foddering by Mongolian pastoralists is recorded in the stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes of caprine dentinal collagen' *Journal of Archaeological Science* 33: 862–70

Manhart, H. 1998: *Die vorgeschichtliche Tierwelt von Koprivec und Durankulak und anderen prähistorischen Fundplätzen in Bulgarien aufgrund von Knochenfunden aus archäologischen Ausgrabungen* (Documenta naturae 116). Munich

Masseti, M., Cavallaro, A., Pecchioli, E., Vernesi, C. 2006: 'Artificial occurrence of fallow deer, *Dama dama dama* (L., 1758), on the island of Rhodes (Greece): insight from mtDNA analysis' *Journal of Human Evolution* 21.2: 167–75

Meadow, R. 1981: 'Early animal domestication in South Asia: a first report on the faunal remains from Mehrgarh, Pakistan' in H. Härtel (ed.), *South Asian Archaeology*. Berlin: 143–79

— 1999: 'The use of size index scaling techniques for research on archaeozoological collections from the Middle East' in C. Becker, H. Manhart, J. Peters, J. Schibler (eds), *Historia Animalium Ex Ossibus: Beitrage zur Palaoanatomie, Archaologie, Agyptologie, Ethnologie, und Geschichte der Tiermedizin*. Rahden: 285–300

Megaloudi, F. 2005: 'Archaeobotanical finds from Ulucak, western Turkey (Izmir region): a preliminary study' *Mediterranean Archaeology and Archaeometry (Special Issue on Ulucak)* 5.3: 27–32

Mellaart, J. 1964: *Anatolia Before c. 4000 BC and c. 2300–1750 BC*. Cambridge

O'Connor, T. 2000: *The Archaeology of Animal Bones*. London

Özdoğan, M. 2011: 'Archaeological evidence on the westward expansion of farming communities from eastern Anatolia to the Aegean and the Balkans' *Current Anthropology* 52.S4: 415–30

Payne, S. 1972: 'Partial recovery and sample bias. The results of some sieving experiments' in E.S. Higgs (ed), *Papers in Economic Prehistory*. Cambridge: 49–64

— 1973: 'Kill-off patterns in sheep and goats: the mandibles from Aşvan Kale' *Anatolian Studies* 23: 281–303

— 1985: 'Animal bones from Aşıklı Höyük' *Anatolian Studies* 35: 109–22

Payne, S., Bull, G. 1988: 'Components of variation in measurements of pig bones and teeth, and the use of measurements to distinguish wild from domestic pig remains' *Archaeozoologica* 2: 27–66

Pearson, J.A., Buitenhuis, H., Hedges, R., Martin, L., Russell, N., Twiss, K. 2007: 'New light on early caprine herding strategies from isotope analysis: a case study from Neolithic Anatolia' *Journal of Archaeological Science* 34.12: 2170–79

Pross, J., Kotthoff, U., Müller, U.C., Dormoy, I., Schmiedl, G., Kalaitzidis, S., Smith, A.M. 2009: 'Massive perturbation in terrestrial ecosystems of the eastern Mediterranean region associated with the 8.2 kyr B.P. climatic event' *Geology* 37: 887–90

Prummel, W., Frisch, H.J. 1986: 'A guide to the distinction of species, sex and body side in bones of sheep and goats' *Journal of Archaeological Science* 13: 567–78

Redding, R. 1984: 'Theoretical determinants of a herder's decisions: modeling variation in the sheep/goat ratio' in J. Clutton-Brock, C. Grigson (eds), *Animals and Archaeology* 3*, Early Herders and their Flocks* (British Archaeological Reports 202). Oxford: 223–42

Reingruber, A. 2005: 'The Argissa Magoula and the beginnings of the Neolithic in Thessaly' in C. Lichter (ed.), *How Did Farming Reach Europe? Anatolian-European Relations from the Second Half of the 7th Through the First Half of the 6th Millennium Cal. BC* (Byzas 2). Istanbul: 155–71

Reitz, E., Wing, E. 2008: *Zooarchaeology*. Cambridge

Roodenberg, J. 2008: 'Ilıpınar and Menteşe: early settlement in the eastern Marmara region' in D. Bailey, A. Whittle, D. Hofmann (eds), *Living Well Together? Settlement and Materiality in the Neolithic of South-East and Central Europe*. Oxford: 8–16

Russell, N., Martin, L. 2005: 'The Çatalhöyük mammal remains' in I. Hodder (ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 Seasons*. Cambridge: 33–98

Russell, N., Martin, L., Buitenhuis, H. 2005: 'Cattle domestication at Çatalhöyük revisited' *Current Anthropology* 46: 101–08

Sağlamtimur, H. 2007: 'Ege Gübre Neolitik Yerleşimi' in M. Özdoğan, N. Başgelen (eds), *Türkiye'de Neolitik Dönem: Yeni Kazılar, Yeni Bulgular*. Istanbul: 373–76

Sagona, A., Zimansky, P. 2009: *Ancient Turkey*. London.

Scheu, A. 2011: *Palaeogenetische Studien zur Populationsgeschichte von Rind und Ziege mit einem Schwerpunkt auf dem Neolithikum in Südosteuropa*. PhD thesis, Johannes Gutenberg-University, Mainz

Sherratt, A. 1981: 'Plough and pastoralism: aspects of the Secondary Products Revolution' in I. Hodder, G. Isaac, N. Hammond (eds), *Pattern of the Past: Studies in Honor of David Clarke*. Cambridge: 261–306

Silver, I.A.1969: 'The ageing of domestic animals' in D. Brothwell, E. Higgs (eds), *Science in Archaeology*. London: 283–302

Thissen, L., Özbal, H., Türkekul Bıyık, A., Gerritsen, F., Özbal, R. 2010: 'The land of milk? Approaching dietary preferences of Late Neolithic communities in NW Anatolia' *Leiden Journal of Pottery Studies* 26: 157–72

Trantalidou, C. 1990: 'Animals and human diet in the prehistoric Aegean' in D.A. Hardy (ed.), *Thera and the Aegean World*. London: 393–405

— 2005: 'Faunal exploitation at the Ulucak Höyük area: preliminary report' *Mediterranean Archaeology and Archaeometry (Special Issue on Ulucak)* 5.3: 47–61

Uerpmann, H.-P. 1973: 'Animal bone finds and economic archaeology: a critical study of osteo-archaeological method' *World Archaeology* 4.3: 307–22

— 1979: *Probleme der Neolithisierung des Mittelmeerraums* (Beihefte zum Tübinger Atlas des vorderen Orients). Wiesbaden

— 1987: *The Ancient Distribution of Ungulate Mammals in the Middle East* (Beihefte zum Tubinger Atlas des Vorderen Orients). Wiesbaden

— 1993: 'Proposal for a separate nomenclature of domestic animals' in A.T. Clason, S. Payne, H-P. Uerpmann (eds), *Skeletons in Her Cupboard. Festschrift for Juliet Clutton-Brock*. Oxford: 239–41

Uerpmann, M., Uerpmann, H.-P. 1994: 'Animal bone finds from excavation 520 at Qala'at al-Bahrain' in F. Höljund, H. Anderson (eds), *Qala'at al-Bahrain. 1. The Northern City Wall and the Islamic Fortress*. Aarhus: 417–44

van der Plicht, J., Akkermans, P.M.M.G., Nieuwhuyse, O., Kaneda, A., Russell, A. 2011: 'Tell Sabi Abyad, Syria: radiocarbon chronology, cultural change, and the 8.2 ka event' *Radiocarbon* 53.2: 229–43

van Zeist, W., Bottema, S. 1991: *Late Quaternary Vegetation of the Near East* (Beihefte zum Tubingen Atlas des vorderen Orients). Wiesbaden

Vermoere, M., Degryse, P., Vanhecke, L., Muchez, P., Paulissend, E., Smets, E., Waelkens, M. 1999: 'Pollen analysis of two travertine sections in Başköy (southwestern Turkey): implications for environmental conditions during the early Holocene' *Review of Palaeobotany and Palynology* 105: 93–110

Vigne, J.-D., Carrère, I., Briois, F., Guilaine, J. 2011: 'The early process of mammal domestication in the Near East: new evidence from the Pre-Neolithic and Pre-Pottery Neolithic in Cyprus' *Current Anthropology* 52.S4: 255–71

Vigne, J.-D., Helmer, D. 2007: 'Was milk a "secondary product" in the Old World Neolithisation process? Its role in the domestication of cattle, sheep and goats' *Anthropozoologica* 42.2: 9–40

von den Driesch, A. 1976: *A Guide to the Measurement of Animal Bones from Archaeological Sites* (Peabody Museum Bulletin 1). Cambridge MA

— 1987: 'Haus- und Jagdtiere im vorgeschichtlichen Thessalien' *Prähistorische Zeitschrift* 62.1: 1–21

Weninger, B., Alram-Stern, E., Bauer, E., Clare, L., Danzeglocke, U., Jöris, O., Kubatzki, C., Rollefson G., Todorova, H., van Andel, T. 2006: 'Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean' *Quaternary Research* 66: 401–20

Zeder, M.A. 1998: 'Environment, economy and subsistence in northern Mesopotamia' in M. Fortin, O. Aurenche (eds), *Espace Naturel, Espace Habité en Syrie de Nord* (Canadian Society for Mesopotamian Studies Bulletin 33). Quebec: 55–66

— 2001: 'A metrical analysis of a collection of modern goats (*Capra hircus aegargus* and *Capra hircus hircus*) from Iran and Iraq: implications for the study of caprine domestication' *Journal of Archaeological Science* 28: 61–79

— 2006: 'Reconciling rates of long-bone fusion and tooth eruption and wear in sheep (*Ovis*) and goat (*Capra*)' in D. Ruscillo (ed.), *Ageing and Sexing Animals from Archaeological Sites*. Oxford: 87–118

Zeder, M.A., Hesse, B. 2000: 'The initial domestication of goats (Capra hircus) in the Zagros mountains 10,000 years ago' *Science* 287: 2254–57

Zeder, M.A., Lapham, H. 2010: 'Assessing the reliability of criteria used to identify postcranial bones in sheep, *Ovis*, and goats, *Capra*' *Journal of Archaeological Science* 37.11: 2887–905

Zeder, M.A., Pilaar, S. 2010: 'Assessing the reliability of criteria used to identify mandibles and mandibular teeth in sheep, *Ovis*, and goats, *Capra*' *Journal of Archaeological Science* 37: 225–42